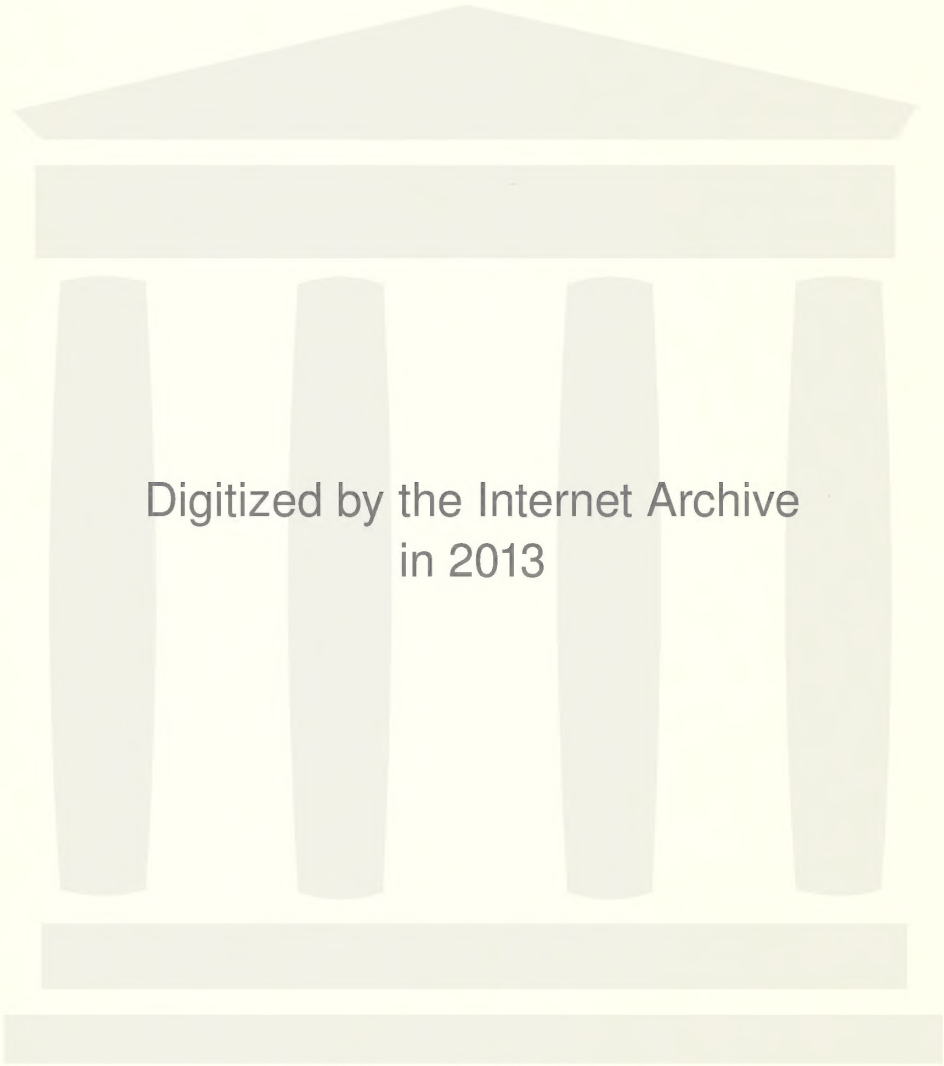

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USDA Forest Service
General Technical Report RM-36
April 1977

Fungal Parasites of Dwarf Mistletoes



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Abstract

At least eight fungi are known to parasitize dwarf mistletoe shoots in North America. Three of these (*Colletotrichum gloeosporioides, Cylindrocarpon gillii,* and *Wallrothiella arceuthobii*) are common and occur on most of the dwarf mistletoes in the western United States. *Pestalotia heterocornis* and *Cylindrocarpon* sp. are reported for the first time as dwarf mistletoe parasites. The other three fungi (*Pestalotia maculiformans, Metaspheria wheeleri,* and *Alternaria alternata*) are rare or local as mistletoe parasites. Although some of these fungi may decimate dwarf mistletoe shoots and fruits in certain localities in certain years, their overall role in limiting dwarf mistletoes seems to be minor.

Keywords: *Colletotrichum gloeosporioides, Cylindrocarpon gillii, Wallrothiella arceuthobii,* hyperparasites, biological control.

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Fungal Parasites of Dwarf Mistletoes

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Acknowledgments

We thank Don Knutson, USDA Forest Service, Corvallis, Oregon for providing collections and locations for fungi in the Pacific Northwest. Also, we gratefully acknowledge the assistance of Dr. E. Guba in identifying *Pestalotia heterocornis*.

[1]*Central headquarters maintained at Fort Collins in cooperation with Colorado State University.*





The three most common fungus parasites of dwarf mistletoe:
Coletotrichum gloeosporioides on *Arceuthobium abietinum* (upper left): the tips of the mistletoe shoots have been killed by the fungus.
Cylindrocarpon gillii on *Arceuthobium campylopodum* (upper right): fruiting bodies showing masses of white spores; shoots are girdled and killed distal to the infection.
Wallrothiella arceuthobii on *Arceuthobium douglasii* (lower): nearly every mistletoe fruit is parasitized by the fungus (black tips). Only a few normal (nonparasitized) fruits remain.



Fungal Parasites of Dwarf Mistletoes

Frank G. Hawksworth, Ed F. Wicker and Robert F. Scharpf

INTRODUCTION

The dwarf mistletoes (*Arceuthobium* spp.) are widespread parasites of conifers in western North America (Hawksworth and Wiens 1972). This Paper summarizes the literature and our observations on distribution of parasitic fungi associated with dwarf mistletoes and discusses their potential as biological control agents. It is restricted to fungi that parasitize the aerial shoots of dwarf mistletoes, and does not consider fungi that may be associated with dwarf mistletoe root systems within the host, such as *Cytospora abietis* on true firs (Scharpf 1969). Information on several such dwarf mistletoe "canker fungi" is summarized by Hawksworth (1972). The area considered in this Paper includes the western United States, Mexico, and the Caribbean.

Kuijt (1963) summarized the distribution of two fungal hyperparasites of *Arceuthobium* in western Canada: *Wallrothiella arceuthobii* and *Cylindrocarpon gillii. Colletotrichum gloeosporioides* was not recognized by Kuijt, and several of his reports of *C. gillii* are based on misidentification of *C. gloeosporioides* (Muir 1967). Wicker and Shaw (1968) reported several fungal parasites of dwarf mistletoes in the Pacific Northwest.

THE FUNGAL PARASITES

Eight fungal parasites of dwarf mistletoe shoots are presently known in North America (table 1), two of which are reported here for the first time. Only three—*Colletotrichum gloeosporioides, Cylindrocarpon gillii,* and *Wallrothiella arceuthobii*—are widely distributed; the others are known only from limited areas.

The host distribution of the three major fungi on the dwarf mistletoes of the western United States is given in table 2. Note that *Arceuthobium gillii,* which occurs in extreme southern Arizona, is the only western dwarf mistletoe that has not been reported to have been parasitized by these fungi. Several other dwarf mistletoes occur in Mexico (Hawksworth and Wiens 1972), but these fungi have been found there only on species that also occur in the United States: *A. blumeri, A. divaricatum,* and *A. douglasii.* The three primary fungi are known in all western States where dwarf mistletoes occur, except Alaska. Their distribution in Mexico is poorly known; they have so far been collected in only four States. These three fungi also occur in four western Canadian Provinces: British Columbia, Alberta, Saskatchewan, and Manitoba (Kuijt 1963, Muir 1967).

Table 1.—Parasitic fungi found on shoots of *Arceuthobium* spp.

Fungus	Locality	References
Colletotrichum gloeosporioides Penz. (Melanconiales)	Western U.S., Canada, and Mexico	Hawksworth et al. 1968; Muir 1973; Parmeter et al. 1959; Scharpf 1964; Wicker 1967; Wicker and Shaw 1968.
Cylindrocarpon gillii (Ellis) J. A. Muir (*Septogloeum gillii* Ellis) (Melanconiales)	Western U.S., Canada, and Mexico	Ellis 1939, 1946; Gill 1935, 1952; Kuijt 1963; Mielke 1959; Muir 1973; Wicker and Shaw 1968.
Cylindrocarpon sp. (Melanconiales)	Southern Mexico	First reported in this paper.
Wallrothiella arceuthobii (Peck) Sacc. (Sphaeriales)	U.S., Canada, and Mexico	Dowding 1931; Hawksworth 1961; Kuijt 1963, 1969; Knutson and Hutchins 1974; Parker 1970; Peck 1875; Weir 1915; Wicker and Shaw 1968.
Alternaria alternata (Fr.) Keissler (A. tenuis Nees.) (Moniliales)	Manitoba, Canada	Sutton 1973.
Metasphaeria wheeleri Linder (Sphaeriales)	California	Linder 1938.
Pestalotia maculiformans Guba & Zeller (Melanconiales)	Washington	Wicker and Shaw 1968.
Pestalotia heterocornis Guba (Melanconiales)	Dominican Republic	First reported in this paper.

Table 2.—Known hosts of the three major fungal parasites of dwarf mistletoes in the western United States.

Arceuthobium	*Colletotrichum gloeosporioides*	*Cylindrocarpon gillii*	*Wallrothiella arceuthobii*
A. abietinum			
f. sp. *concoloris*	X	X	—
f. sp. *magnificae*	X	X	—
A. americanum	X	X	X
A. apachecum	X	X	—
A. blumeri	—	X	—
A. californicum	X	X	—
A. campylopodum	X	X	—
A. cyanocarpum	—	X	—
A. divaricatum	X	X	—
A. douglasii	X	X	X
A. gillii			
subsp. *gillii*	—	—	—
A. laricis	X	X	—
A. microcarpum	X	X	—
A. occidentale	X	—	—
A. tsugense	X	X	—
A. vaginatum			
subsp. *cryptopodum*	—	—	X[1]

[1]Extremely rare.

Colletotrichum gloeosporioides

This fungus was first reported on *Arceuthobium abietinum* in California by Parmeter et al. (1959), although Wicker and Shaw (1968) show that it was recognized by J. R. Weir (as "*Gloeosporium* sp.") in the Pacific Northwest prior to 1920. The fungus has been recorded on 12 of the 16 dwarf mistletoes in the western United States (table 2).

C. gloeosporioides is one of the most widely distributed of the dwarf mistletoe parasites (fig. 1). It is known from all western States except Nevada and Wyoming, and occurs in Baja California, Mexico (Hawksworth et al. 1968). There is a rather large gap in the known range of the fungus in the Great Basin area and from southern Colorado to western Montana (fig. 1). It seems likely the fungus is not really absent from this area, but simply has not been found due to a lack of intensive collecting of dwarf mistletoe parasites.

C. gloeosporioides infection first appears as a small brown to black necrotic lesion on the shoots, usually at the nodes. The lesions enlarge, coalesce, and cause die-back of the shoots (Parmeter et al. 1959, Wicker and Shaw 1968). Although shoots are the site of initial infection, the fungus can grow into the base of the shoot within the host tissue. In an area in California studied by Parmeter et al. (1959), about 80% of the *A. abietinum* shoots were affected by the fungus to some extent. Over half of the dwarf mistletoe plants bore no shoots, apparently due largely to the fungus. Much lower levels of infection were found in several subsequent years. The fungus is apparently very sporadic and only builds up to high levels when weather conditions are favorable.

Wicker (1967) analyzed the effects of the fungus on *A. campylopodum* on ponderosa pine near Spangle, Washington and found that from 35% to 67% of the plants were diseased and 24% of the shoots were killed. Muir (1967) found *C. gloeosporioides* to be destructive to *A. americanum* in several localities in British Columbia and Alberta.

This fungus has several cultivars that differ in cultural characters. However, cross inoculations have shown no host specificity among these different cultivars (Scharpf 1964).

Specimens examined: see Appendix.

Cylindrocarpon gillii

This fungus was identified and discussed as *Fusarium campylopodii* sp. nov. in an unpublished manuscript by J. R. Weir before 1920 (Wicker and Shaw 1968). Gill (1935) was first to publish an account of the fungus. Ellis (1939) tentatively referred the fungus to the genus *Fusarium,* and later formally described it as *Septogloeum gillii* (Ellis 1946). Muir (1973) transferred it to the genus *Cylindrocarpon.* The fungus is now known to parasitize all but 3 of the 16 dwarf mistletoes in the western United States

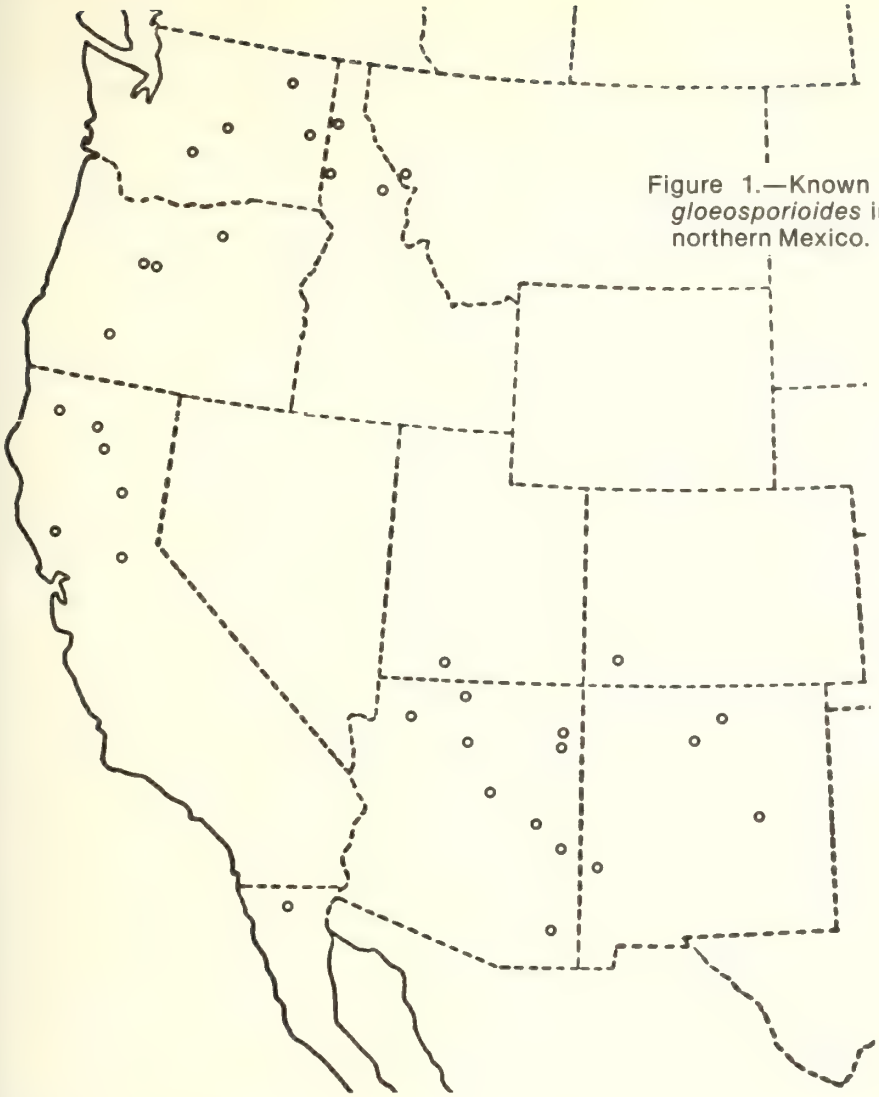


Figure 1.—Known distribution of *Colletotrichum gloeosporioides* in the western United States and northern Mexico.

(table 2). Hundreds of populations of *A. vaginatum* subsp. *cryptopodum* have been examined for the parasite, many where the fungus occurs on associated species, but all without success. Ellis (1946) was able to obtain infection of this dwarf mistletoe by wounding the shoots, but could not infect unwounded tissue.

Cylindrocarpon gillii is widespread on dwarf mistletoe from British Columbia and Alberta (Kuijt 1969), throughout the western United States (fig. 2), and into northern Mexico (Durango and Nuevo León). We have seen few collections of the fungus from Montana, Wyoming or Idaho but we suspect that intensive searches will reveal it is widely distributed in these areas also.

Early infection stages of *C. gillii* are characterized by small, yellowish-white lesions on the shoots. Lesions gradually enlarge, coalesce, and erupt irregularly through the epidermis, disclosing conspicuous white spore masses. Portions of shoots or entire shoots distal to the point of infection are killed (Ellis 1946). The fungus sometimes parasitizes dwarf mistletoe fruits. Both pistillate and staminate plants are attacked. Ellis (1946) says the fungus is more frequent on pistillate plants, but Wicker and Shaw (1968) reported that the fungus showed no preference for either sex of dwarf mistletoe plants. The disease has been reported to exert a considerable degree of natural control over *Arceuthobium microcarpum* and *A. apachecum* (as *A. campylopodum* f. *cyanocarpum*) in Arizona (Ellis 1946) and in *A. tsugense* in Washington (Gill 1935).

Mielke's (1959) study of *Cylindrocarpon gillii* is apparently the only attempt to introduce a fungus into a new area to control a dwarf mistletoe. He inoculated isolates of the fungus from *Arceu-*

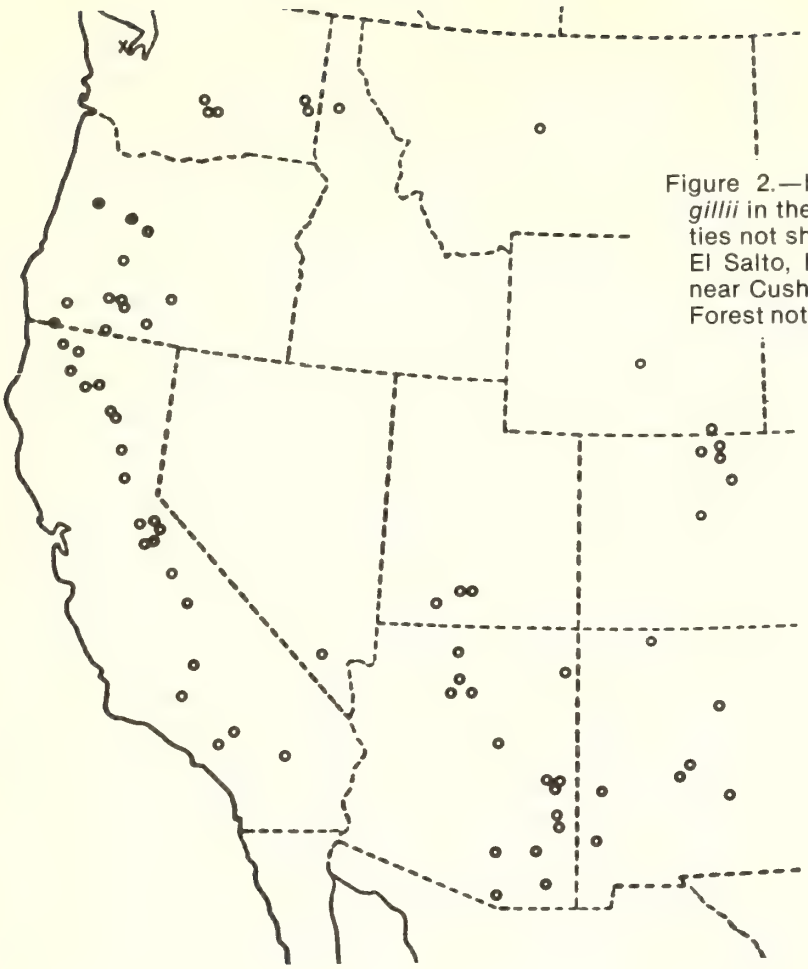


Figure 2.—Known distribution of *Cylindrocarpon gillii* in the western United States. Mexican localities not shown are Cerro Potosí, Nuevo León, and El Salto, Durango. The "x" indicates a location near Cushman Reservoir in the Olympic National Forest noted by Don Knutson.

thobium divaricatum (a parasite of *Pinus edulis*) from northern Arizona onto *A. americanum* (a parasite of *P. contorta*) in southern Idaho and western Wyoming. Although *C. gillii* was observed in the inoculated areas for 3 years following introduction, it did not become established permanently and Mielke concluded that it did not offer hope for biological control. We consider this study inconclusive, however, because it is possible that a more climatically suitable isolate might have become established. *C. gillii* had not been reported on *A. americanum* at the time of Mielke's study, but it is now known on this dwarf mistletoe in Montana (Gill 1952) and elsewhere. Perhaps more important in this instance than host biotype are the different environments of the two dwarf mistletoes and their host trees. Since *A. divaricatum* grows on *Pinus edulis* in a low-elevation, warm, arid climate, it should not be expected that a fungus associated with it would thrive in the cool, montane *Pinus contorta* forests.

Specimens examined: see Appendix.

Cylindrocarpon sp.

In Oaxaca in southern Mexico an apparently undescribed *Cylindrocarpon* occurs on *Arceuthobium guatemalense* Hawksw. and Wiens and on *A. rubrum* Hawksw. and Wiens. The fungus is superficially similar to *C. gillii* and causes similar symptoms, but it has much larger spores. Further study, particularly of the fungus in culture, is needed before its taxonomic status can be determined.

Wallrothiella arceuthobii

This is the first fungus parasite reported on the dwarf mistletoes (Peck 1875). Comprehensive studies of the fungus have been made by Weir (1915), Dowding (1931), Wicker and Shaw (1968), Kuijt (1969), Parker (1970), and Knutson and Hutchins (1974). This fungus is unique in that it parasitizes only the pistillate plants of spring-flowering dwarf mistletoes.

Wallrothiella arceuthobii is known on only four dwarf mistletoes; *Arceuthobium pusillum* (Peck 1875) in the East, and three in the West (table 2). It is common on *A. americanum* and *A. douglasii*, but extremely rare on *A. vaginatum* subsp. *cryptopodum* (Hawksworth 1961).

The presently known distribution of *W. arceuthobii* shows a large gap of nearly 700 miles between the northern (Oregon, Washington, Idaho, Montana) and southern (Colorado, Arizona, New Mexico, Mexico) populations (fig. 3). The northwest population occurs principally on *A. douglasii* and occasionally on *A. americanum*. The southern population is known almost exclusively on *A. douglasii* (with the exception of the single collection on *A. vaginatum* subsp. *cryptopodum* from New Mexico). We have searched in many areas within the gap but have failed to discover additional localities. For this reason, and the fact that we have not found the fungus on dwarf mistletoe herbarium material from anywhere within this region, we suspect the gap is real. Comparative morphological studies of the northern and southern populations should be made.

Infection by *Wallrothiella arceuthobii* is confined to the floral area. The stigma and apical portions of the fruit are replaced with a stroma of the fungus. Normal fruit development is prevented and the affected fruits do not produce seeds. The extent of natural control exerted by *W. arceuthobii* has not been determined. Infection in a given area may be quite variable from year to year. One year's crop may have 90% or more of the fruits destroyed, yet the fungus may be nearly absent in the same locality the following year.

Specimens examined: see Appendix.

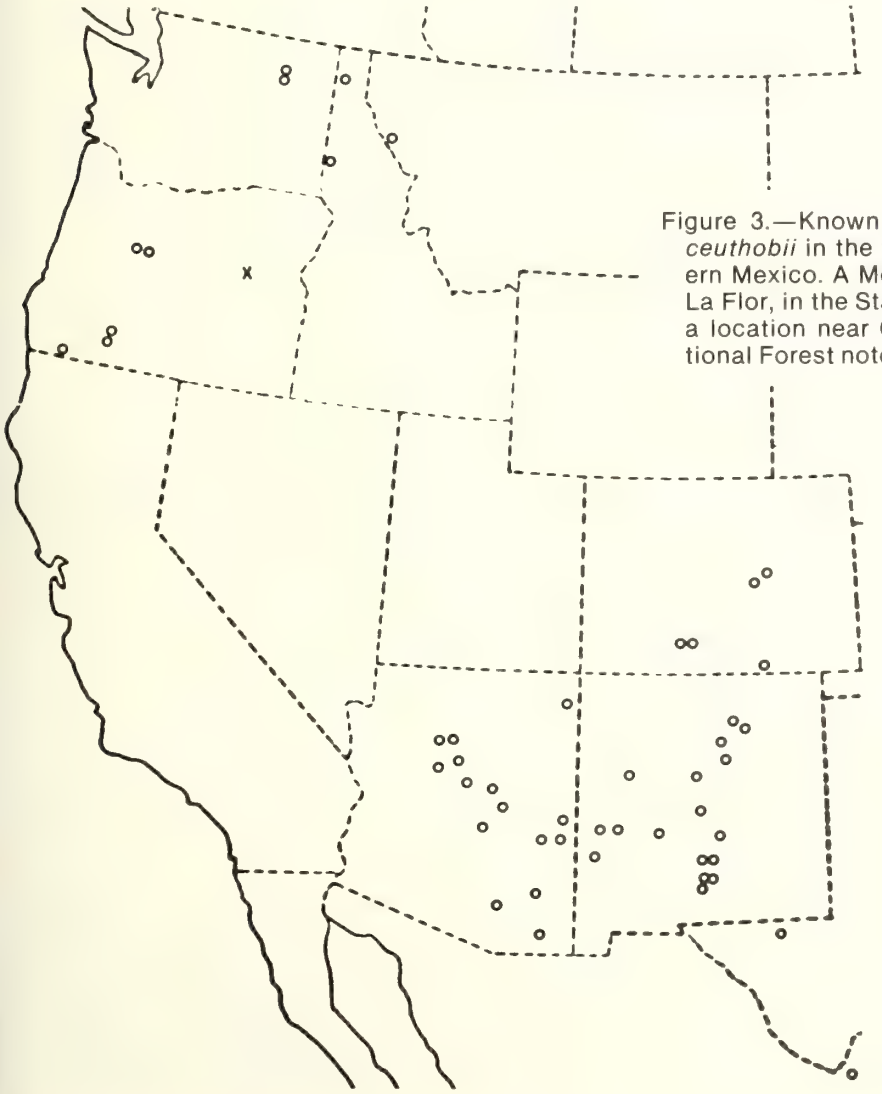


Figure 3.—Known distribution of *Wallrothiella arceuthobii* in the western United States and northern Mexico. A Mexican locality not shown is near La Flor, in the State of Durango. The "x" indicates a location near Crane Prairie in the Malheur National Forest noted by Don Knutson.

Alternaria alternata

The only record of this fungus as a parasite of dwarf mistletoe shoots is by Sutton (1973) who reported it on *Arceuthobium pusillum* Peck on white spruce near Gypsumville, Manitoba, Canada. The fungus develops numerous small, black fruiting bodies over the shoots, particularly at the nodes. *Alternaria alternata* is a ubiquitous fungus that is normally saprophytic or mildly parasitic on a great many plants. In this instance the host tree was apparently weakened, because fruiting bodies of the fungus were common not only on dwarf mistletoe shoots but also on the host spruce branches. The fungus is unknown as a pathogen of dwarf mistletoe shoots in the western United States or Mexico. However, it is one of several canker fungi associated with the resin disease complex of *Arceuthobium americanum* on lodgepole pine in the Rocky Mountains (Mark et al. 1976).

Specimens examined: on *Arceuthobium pusillum*, on *Picea glauca*, Amana Bay, 40 miles east of Gypsumville, Manitoba, Canada, collected by D. Shepherd, 1967 (WINF, FPF).[2]

Metasphaeria wheeleri

This fungus is known only from the type collection on *Arceuthobium occidentale* on *Pinus radiata* at Point Lobos, California (Linder 1938). It is reported to infect and kill the shoots of this dwarf mistletoe. Subsequent attempts by W. W. Wagener and R. F. Scharpf to relocate the fungus in this locality and elsewhere in native Monterey pine stands infested with *A. occidentale* have been unsuccessful. The presence of *M. wheeleri* in the type specimen was confirmed, however, by Scharpf in 1969. This fungus is either exceedingly rare or highly sporadic in occurrence in its reported locality. It shows no promise as a biological control agent.

Specimens examined: on *Arceuthobium occidentale*, on *Pinus radiata*, Point Lobos, Monterey, California, by L. C. Wheeler (FPB).

Pestalotia maculiformans

The only report of this fungus on dwarf mistletoes is by Wicker and Shaw (1968) who found it on *Arceuthobium tsugense* near White Pass Summit, Washington. Numerous individual fruiting structures develop subepidermally on infected shoots, and appear as pale yellow flecks. Fruiting bodies may coalesce and assume an irregular shape. As they mature, they erupt irregularly through the cuticle and epidermis of the dwarf mistletoe shoot, exposing the mass of dark colored conidia. Fruiting structures more closely resemble pycnidia than acervuli because they show a greater degree of development than a "cushion-like mass of hyphae having conidiophores and conidia." The hyphae of the fruiting structures form subglobose, hollow fruiting bodies with conidiophores inside (fig. 4).

Since the fungus has not been previously described in *Arceuthobium*, we have prepared the following description: Conidia are fusoid, straight or slightly curved, 5-celled, slightly constricted at septa, 21.5–28.5 by 5.9–8.4 μ (50 spores); apical cell hyaline, long cylindric, typically supporting 3 setulae; basal cell hyaline, long conic, acute; 3, contrasted colored, intermediate cells, upper 2 umber, lowest olive or pale brown, not swollen across middle, guttulate, walls darker, setulae non-spathulate, hyaline, 15.0–22.5 μ (50 spores).

Mycelial development within infected shoots is rather sparse, intercellular, and confined to the parenchymatous matrix of the stem. We have observed no hyphae of the fungus to penetrate the vascular tissues.

The dwarf mistletoe shoots in the specimen were already dead at the time of collection. However, inoculations of live dwarf mistletoe shoots with the fungus showed that it is parasitic.

Specimens examined: on *Arceuthobium tsugense* (as *A. campylopodum* f. *abietinum*) on *Abies amabilis*, 3 miles west of White Pass, Lewis County, Washington, collected by Ed Wicker, 1962 (WSP 54146).

Pestalotia heterocornis

This fungus (Guba 1961) is reported here for the first time on a dwarf mistletoe. It was found in a collection of *Arceuthobium bicarinatum*, a parasite of *Pinus occidentalis* in the Dominican Republic. Its effects on dwarf mistletoe are not known but apparently minor.

Mycelial development within infected shoots: intercellular, sparse, distributed throughout the parenchymatous matrix and vascular tissues. Initial development of fruiting body a mass of loose, intertwining hyphae; at maturity compact, dark, lenticular, pseudoparenchymatous, punctiform, subepidermal, erumpent, irregularly rupturing

[2]See Appendix for abbreviations of the herbaria cited.

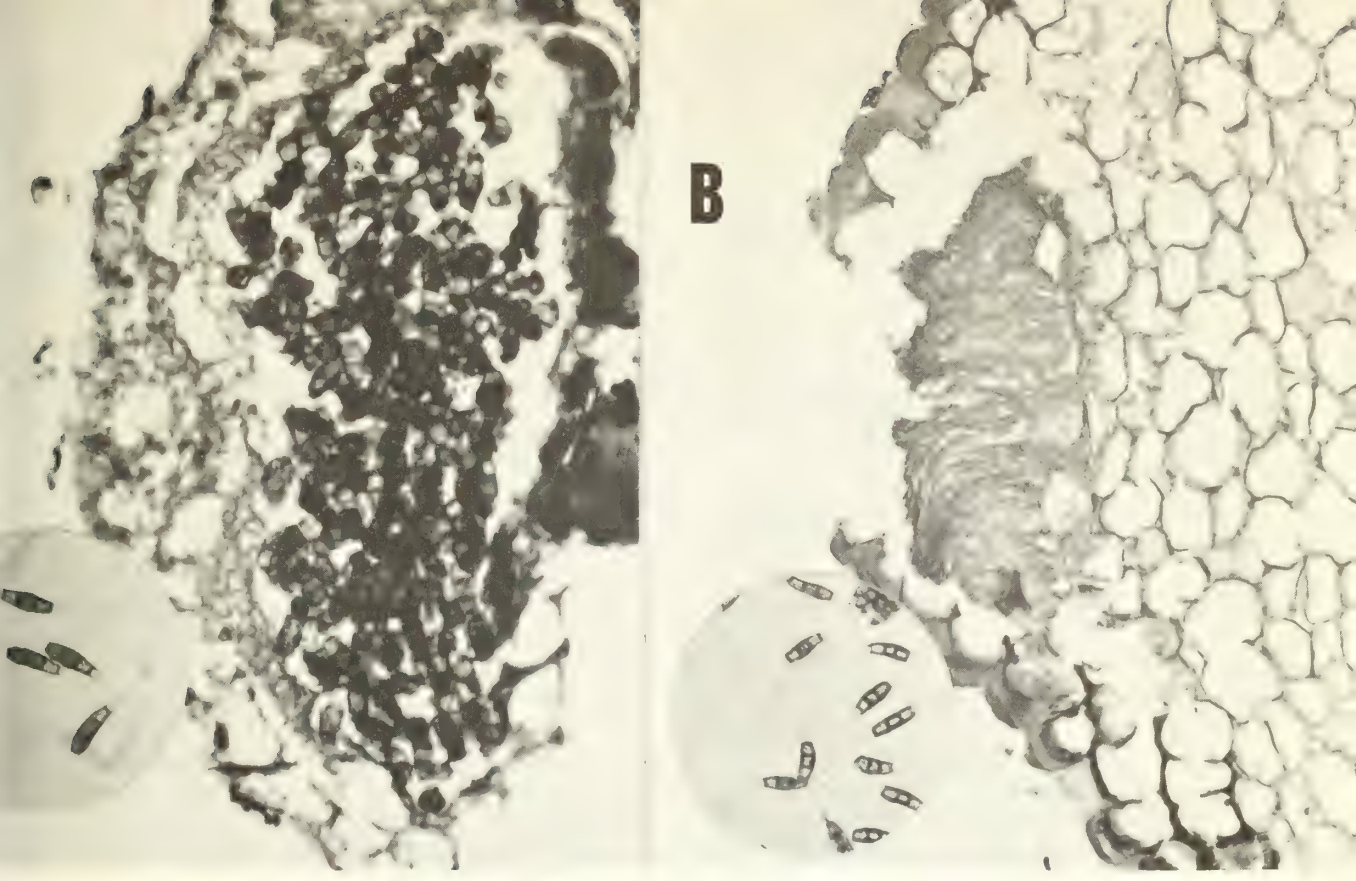


Figure 4.—Fruiting bodies and conidia of 2 species of *Pestalotia* on dwarf mistletoe shoots.
A. *Pestalotia maculiformans* X 325, Conidia X 270. B. *Pestalotia heterocornis* X 175, Conidia X 270.

the epidermis (fig. 4). Pustules appear as pale yellow flecks on the shoots and often coalesce and assume an irregular shape. Fruiting body more closely resembles an acervulus than a pycnidium.

Description of the fungus: Conidia: narrow fusiform, straight or slightly curved, 5-celled, tapering at extremities, slightly constricted at septa, 21–27 μ by 5.0–6.8 μ (25 spores). Basal cell hyaline, long acute. Apical cell hyaline, long turbinate. Three intermediate colored cells olivaceous-pale brown, concolorous, guttulate, walls darker. Setulae hyaline, 1–3, most commonly 2, unequal in length 7–27 μ long, one stronger, a prolongation of apical cells, attenuated and the other 1 or 2 setulae filliform, subapical, arising along the slope of the apical cell or often irregularly arranged at crest of apical cell, 2–3 joined at crest or sometimes distinct. Pedicels 3–8 μ long.

Specimens examined: on *Arceuthobium bicarinatum* Urban, on *Pinus occidentalis,* Las Canitas, elevation 4,125 ft, Dominican Republic, collected by A. F. Gasbarro, 1963 (FPF 1209).

CONCLUSIONS

At least eight fungi are known to be parasitic on the shoots of dwarf mistletoes in North America. Three of these (*Colletotrichum gloeosporioides, Cylindrocarpon gillii,* and *Wallrothiella arceuthrobii*) are common and occur on most of the dwarf mistletoes in the western United States. *Pestalotia heterocornis* and *Cylindrocarpon* sp. are reported for the first time as dwarf mistletoe parasites. The other three fungi (*Pestalotia malculiforman, Metaspheria wheeleri,* and *Alternaria alternata*) are rare or local as dwarf mistletoe parasites. Although *C. gloeosporioides, C. gillii,* and *W. arceuthobii* may severely reduce the shoots and seed crops of *Arceuthobium* in certain localities in certain years, their overall role in limiting these parasites seems to be minor. Similarly, since these are native fungi acting on native hosts, the possibilities of their use as biological control agents seem remote.

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Appendix

Collections examined of the three major dwarf mistletoe hyperparasites.

Abbreviations for herbarium of collections cited are:

FPB — Forest Pathology Herbarium, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

FPF — Forest Pathology Herbarium, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

GH — Gray Herbarium, Harvard University, Cambridge, Mass.

ILL — University of Illinois Herbarium, Urbana, Illinois.

WSP — Plant Pathology Herbarium, Washington State University, Pullman, Washington.

WINF — Forest Pathology Herbarium, Canadian Forest Service, Edmonton, Alberta.

Colletotrichum gloeosporioides

Arceuthobium abietinum

on *Abies concolor*

CALIFORNIA: PLUMAS CO., Grizzly Creek on Oroville-Quincy Road, *Scharpf* in 1964 (FPB 98106). *TUOLUMNE CO.,* 10 miles S of Long Barn, *Scharpf* in 1967 (FPB 98131).

on *Abies grandis*

OREGON: JEFFERSON CO., 3 miles E of Santiam Pass, *Hawksworth and Scharpf 1257* in 1969 (FPF).

on *Abies magnifica*

CALIFORNIA: PLUMAS CO., Grizzly Summit on Oroville-Quincy Road, *Scharpf* in 1964 (FPB 98107).

Arceuthobium americanum

on *Pinus contorta*

CALIFORNIA: PLUMAS CO., 1 mile W of Bucks Lake on Oroville-Quincy Road, *Scharpf* in 1964 (FPB 98105).

MONTANA: MISSOULA CO., 1 mile SW of Lolo Hot Springs on U.S. 12, *Hawksworth and Laut 1290* in 1970 (FPF).

OREGON: JACKSON CO., 5 miles E of Union Creek on Route 62, *Hawksworth 1375* in 1971 (FPF).

WASHINGTON: KITTITAS CO., 18 miles N of Teanaway, *Wicker* in 1966 (WSP 56496, FPF 2459).

Arceuthobium apachecum

on *Pinus strobiformis*

ARIZONA: COCHISE CO., Chiricahua Mts., *Mielke and Ellis* in 1944 (FPF 89697).

Arceuthobium californicum

on *Pinus lambertiana*

CALIFORNIA: PLUMAS CO., Fananin Meadows—Butte Creek, near Lake Almanor, *Scharpf* in 1971 (FPB 98605).

Arceuthobium campylopodum

on *Pinus attenuata*

CALIFORNIA: SISKIYOU CO., McCloud, *Scharpf* in 1965 (FPB 98113).

on *Pinus jeffreyi*

CALIFORNIA: ELDORADO CO., Placerville, *Hawksworth 1319* in 1971 (FPF). *SHASTA CO.,* Burney Falls, *Scharpf* in 1965 (FPB 98114).

on *Pinus ponderosa*

CALIFORNIA: SISKIYOU CO., McCloud, *Scharpf* in 1965 (FPB 98111).

IDAHO: KOTENAI CO., Coeur d'Alene, *Weir 9866* in 1915 (ILL).

OREGON: WHEELER CO., 26 miles S of Hardmann, *Hawksworth and Scharpf 1271* in 1969 (FPF) (FPB 98656).

WASHINGTON: SPOKANE CO., Spokane, *Weir 8475* in 1917 (ILL); 3 miles N of Spangle, *Wicker* in 1963 (WSP 54002, WSP 51932).

Arceuthobium divaricatum

on *Pinus edulis*

ARIZONA: APACHE CO., Canyon de Chelly Natl. Mon., *Lightle et al.* in 1965 (FPF 2150). Sawmill, *Lightle and Weiss* in 1966 (FPF 2498). *COCONINO CO.,* Grand Canyon Natl. Park, South Rim, *Hawksworth* in 1954 (FPF 1760); Long Valley, *Ellis* in 1939 (FPF 89426); Jacob Lake, *Ellis* in 1939 (FPF 89419). *MOHAVE CO.,* Grand Canyon Natl. Mon., 6 miles S of Mt. Trumbull, *Hawksworth 1165* in 1969 (FPF).

COLORADO: MONTEZUMA CO., North Entrance, Mesa Verde Natl. Park, *Scharpf and Hawksworth* in 1964 (FPB 98108, FPF 1727); 2 miles E of Cortez, *Wicker* in 1967 (WSP 57618).

NEW MEXICO: CATRON CO., 8 miles SE of Apache Creek, *Lightle* in 1965 (FPF 2154). *LINCOLN CO.,* Gallinas Mts., *Hawksworth 1078* in 1967 (FPF). *SANDOVAL CO.,* 14 miles NW of Cuba, *Hawksworth and Scharpf 692* in 1964 (FPF). *TAOS CO.,* 12 miles S of Tres Piedras, *Hawksworth 1011* in 1967 (FPF).

UTAH: KANE CO., Glendale, *Wiens 3179* in 1962 (FPF).

on *Pinus quadrifolia*

MEXICO: BAJA CALIFORNIA, Sierra Juarez, *Scharpf and Hawksworth* in 1965 (FPB 98110, FPF 1948).

Arceuthobium douglasii

on *Pseudotsuga menziesii*

IDAHO: LATAH CO., 3 miles E of Viola, *Wicker* in 1963 (WSP 54005).

WASHINGTON: FERRY CO., Growden, *Wicker* in 1963 (WSP 51931); Lane Creek, *Wicker* in 1964 (WSP 54006) and in 1966 (WSP 56495). *YAKIMA CO.,* Tieton Reservoir, *Wicker* in 1963 (WSP 54007).

Arceuthobium laricis

on *Larix occidentalis*

IDAHO: IDAHO CO., 28 miles W of Lolo Pass on U.S. 12, *Hawksworth 1292* in 1970 (FPF).

OREGON: JEFFERSON CO., 2 miles W of Camp Sherman, *Hawksworth and Scharpf 1258* in 1969 (FPF, FPB 98655).

WASHINGTON: FERRY CO., Growden, *Wicker* in 1962 (WSP 52723) and 1963 (WSP 54004) and 1964 (WSP 54003).

Arceuthobium microcarpum

on *Picea pungens*

ARIZONA: APACHE CO., 5 miles SW of Alpine, *Scharpf and Hawksworth* in 1964 (FPB 98109, FPF 1736); 10 miles E of McNary, *Hawksworth 1083* in 1967 (FPF). *GREENLEE CO.,* Hannagan Meadows, *Hawksworth 1082* in 1968 (FPF).

Arceuthobium occidentale

on *Pinus sabiniana*

CALIFORNIA: CONTRA COSTA CO., Mt. Diablo State Park, *Scharpf* in 1959 (FPB 98712). *NAPA CO.,* Middletown, *Scharpf* in 1965 (FPB 98112).

Arceuthobium tsugense

on *Tsuga mertensiana*

CALIFORNIA: SISKIYOU CO., Marble Mts., Chimney Rock Lake, *Hemphill* in 1968 (FPF 2812).

Arceuthobium abietinum

on *Abies concolor*

ARIZONA: COCONINO CO., Grand Canyon Natl. Park, North Rim, *Gill and Ellis 1939* (FPF 89417) and *Hawksworth 252* and *254* in 1962 (FPF).

CALIFORNIA: ALPINE CO., 8 miles SW of Silver Creek, *Hawksworth and Scharpf 667* in 1964 (FPF). *DEL NORTE CO.,* just S of Calif. line on O'Brien-Happy Camp Rd., *Hawksworth and Hinds 999* in 1966 (FPF). *SAN BERNARDINO CO.,* Camp Angelus, *Wiens 3210* in 1962 (FPF). *SHASTA CO.,* Lassen Natl. Park, 4 miles N of N entrance, *Hawksworth and Wiens 648* in 1964 (FPF). *SISKIYOU CO.,* Mt. Shasta, *Hawksworth and Wiens 641* in 1964 (FPF); Joe Creek, 10 miles S of Copper, Oregon, *Hawksworth and Wiens 635* in 1964 (FPF).

NEVADA: CLARK CO., Charleston Mts., *Scharpf and Hawksworth* in 1964 (FPB 98123); *Clokey 5433* in 1935 (FPF).

OREGON: KLAMATH CO., 9 miles N of Ft. Klamath on Route 62, *Hawksworth 1377* in 1971 (FPF); 31 miles W of Klamath Falls, *Hawksworth and Wiens 629* in 1964 (FPF). *LAKE CO.,* 8 miles SW of Beatty, *Hawksworth and Wiens 874* in 1966 (FPF); 12 miles SW of Silver Lake, *Stewart* in 1968 (FPF).

UTAH: KANE CO., 8 miles S of Navajo Lake, *Wiens 4122* in 1966 (FPF).

on *Abies grandis*

CALIFORNIA: SISKIYOU CO., near Oregon border on O'Brien-Happy Camp Rd., *Hawksworth and Hinds 998* in 1966 (FPF).

OREGON: DESCHUTES CO., Squaw Creek south of Sisters, *Fender* in 1974 (FPF).

on *Abies magnifica*

CALIFORNIA: CALAVERAS CO., 8 miles SW of Tamarack, *Hawksworth and Scharpf 663* in 1964 (FPF). *FRESNO CO.,* Huntington Lake, *Miller* in 1965 (FPB 98117). *SHASTA CO.,* 10 miles N of North entrance to Lassen Natl. Park, *Hawksworth and Wiens 650* in 1964 (FPF). *TUOLUMNE CO.,* Pinecrest, *Scharpf* in 1963 (FPF 1416) and 1965 (FPB 98122); Yosemite Natl. Park, 7 miles E of Crane Flat, *Hawksworth 938* in 1966 (FPF).

Arceuthobium americanum

on *Pinus contorta*

CALIFORNIA: CALAVERAS CO., 3 miles SW of Tamarack, *Hawksworth and Scharpf 664* in 1964 (FPF).

COLORADO: GRAND CO., 18 miles S of Parshall, *Hawksworth and Hinds* in 1960 (FPF 1419). *JACKSON CO.,* 8 miles NE of Cowdry, *Davidson and Gill* in 1952 (FPF 89991); Pearl, ca 20 miles NW of Cowdry, *Hawksworth 830* in 1965 (FPF); 10 miles NE of Cowdry, *Hawksworth 942* in 1966 (FPF); 2 miles N of Gould, *Hawksworth 1091* in 1968 (FPF). *SUMMIT CO.,* Dillon, *Hawksworth 1640* in 1975 (FPF).

MONTANA: MEAGHER CO., Little Belt Mts., 16 miles N of White Sulfur Springs, *Gill* in 1948 (FPF 89984).

WYOMING: ALBANY CO., Pelton Creek, 4 miles W of Mountain Home, *Hawksworth 1092* in 1968 (FPF). *FREMONT CO.,* Green Mts., *Hawksworth 1691* in 1976 (FPF).

Arceuthobium apachecum

on *Pinus strobiformis*

ARIZONA: APACHE CO., 4 miles S of Eagar, *Hawksworth and Lightle 210* in 1962 (FPF). *COCHISE CO.,* Chiricahua Mts., *Ellis and Gill* in 1939 (FPF 89404); *Ellis* in 1939 (FPF 89423); *Gill and Ellis* in 1940 (FPF 89432); *Mielke and Ellis* in 1944 (FPF 89695). *GRAHAM CO.,* Graham Mts., *Stouffer and Gill* in 1934 (FPF 68292 and 68293); *Gill* in 1936 (FPF 89313); *Ellis* in 1938 (FPF 89401) and 1939 (FPF 89431, 89415 and 89429); *Mielke and Ellis* in 1944 (FPF 89693). *GREENLEE CO.,* Blue Summit, *Ellis* in 1939 (FPF 89413). *PIMA CO.,* Santa Catalina Mts., *Ellis* in 1939 (FPF 89424); *Gill and Ellis* in 1939 (FPF 89407); *Mielke and Ellis* in 1944 (FPF 89696).

NEW MEXICO: CATRON CO., 7 miles E of Mogollon, *Hawksworth and Lightle 929* in 1966 (FPF). *SOCORRO CO.,* Magdalena Mts., North Baldy Mt., *Lightle* in 1966 (FPF 2491); San Mateo Mts., *Hawksworth and Lightle 1117* in 1968 (FPF).

Arceuthobium blumeri

on *Pinus strobiformis*

ARIZONA: SANTA CRUZ CO., Santa Rita Mts., Mt. Wrightson, *Hawksworth 796* in 1965 (FPF).

MEXICO: DURANGO, 19 miles W of Santiago Papasquiaro, *Hawksworth and Wiens 536* in 1963 (FPF). *NUEVO LEON.,* Cerro Potosi, *Hawksworth and Wiens 392* in 1963 (FPF).

Arceuthobium californicum

on *Pinus lambertiana*

CALIFORNIA: PLUMAS CO., 5 miles W of Quincy, *Hawksworth and Wiens 654* in 1964 (FPF). *NEVADA CO.,* Graniteville, *Boyce* in 1917 (FPF 1501).

on *Pinus monticola*

CALIFORNIA: SISKIYOU CO., High Creek Camp, Mt. Eddy, *Scharpf* in 1965 (FPB 98115).

OREGON: COUNTY UNCERTAIN, between Ashland and Klamath Falls, *Weir 3239* in 1916 (FPF). *CURRY CO.,* Saddle Mt., *Bynum* in 1967 (FPF 2638).

Arceuthobium campylopodum

on *Pinus attenuata*

OREGON: JOSEPHINE CO., Oregon Mtn., *Howard* in 1964 (FPF 2369).

on *Pinus coulteri*

CALIFORNIA: LOS ANGELES CO., Mt. Wilson, *Perkins* in 1919 (ILL).

on *Pinus jeffreyi*

CALIFORNIA: ALPINE CO., 1 mile S of Markelville, *Hawksworth 1303* in 1970 (FPF). *LOS ANGELES CO.,* Big Pines, *Hawksworth 728* in 1965 (FPF). *SHASTA CO.,* Manzaniza Chute, *Scharpf* in 1965 (FPB 98118). *TOULUMNE CO.,* Longbarn, *Thomas 5519* in 1963 (FPF).

OREGON: JOSEPHINE CO., Wonder, *Mitchell* in 1932 (FPF 68212).

on *Pinus ponderosa*

CALIFORNIA: CALAVERAS CO., 15 miles SW of Tamarack, *Hawksworth* and *Scharpf 661* in 1964 (FPF). *KERN CO.,* Greenhor Mts., Tiger Flat, *Wiens 3607* in 1964 (FPF *TOULUMNE CO.,* Longbarn, *Wright* i 1932 (FPF 68117).

IDAHO: KOOTENAI CO., Coeur d'Alen Lake, *Wicker* in 1973 (FPF 3212).

NEVADA: CLARK CO., Charleston Mts Kyle Canyon, *Hawksworth and Scharpf 67* in 1964 (FPF).

OREGON: DESCHUTES CO., Pringle Fall Exp. Forest, *Wicker* in 1966 (WSP 5649 and *Hawksworth 989* in 1966 (FPF); Squa Creek south of Sisters, *Knutson* in 197 (FPF). *GRANT CO.,* Lee Creek, 25 mile ESE of Seneca, *Hawksworth and Scharp 1267* in 1969 (FPF).

WASHINGTON: SPOKANE CO., 3 miles I of Spangle, *Wicker* in 1962 (WSP 52733). *YAKIMA CO.,* Tieton Canyon, *Wicker* i 1962 (WSP 52730) and in 1964 (WSP 54012).

Arceuthobium cyanocarpum

on *Pinus flexilis*

UTAH: GARFIELD CO., Bryce Canyo Natl. Park, *Gill* in 1932 (FPF 68144).

on *Pinus monticola*

CALIFORNIA: TRINITY CO., Mt. Eddy *Scharpf* in 1965 (FPB 98115) and *Miller an Bynum* in 1964 (FPF 1768).

Arceuthobium divaricatum

on *Pinus edulis*

ARIZONA: APACHE CO., 8 miles SW o Red Rock, *Lightle and Weiss* in 1966 (FPF 2504). *COCONINO CO.,* Grand Canyon Natl. Park, South Rim, *Hawksworth and Scharp 701* in 1964 (FPF) and *Hawksworth 1088* in 1967 (FPF). Jacob Lake, *Ellis* in 1939 (FPF 89419); *Mielke* in 1944 (FPF 89700), and *Hawksworth and Gill* in 1952 (FPF 89990). 34 miles S of Winslow on Chevelon Rd., *Hawksworth and Lightle 916* in 1966 (FPF).

NEW MEXICO: BERNALILLO CO., Sandia Mts., *Ellis* in 1939 (FPF 89411). *LINCOLN CO.,* Nogal, *Hawksworth and Lightle 101* in 1962 (FPF).

UTAH: GARFIELD CO., Table Cliffs, *Peterson 64-87* in 1964 (FPF).

on *Pinus monophylla*

CALIFORNIA: KERN CO., 31 miles SE of Maricopa, *Wiens 3217* in 1962 (FPF). *MONO CO.*, 5 miles S of Walker on Rt. 395, *Scharpf* in 1970 (FPB 98713).

Arceuthobium douglasii

on *Pseudotsuga menziesii*

ARIZONA: GRAHAM CO., Graham Mts., *Ellis* in 1939 (FPF 89427) and *Mielke and Ellis* in 1944 (FPF 89698). *PIMA CO.*, Santa Catalina Mts., *Ellis* in 1939 (FPF 89425) and *Gill and Ellis* in 1939 (FPF 89406).

Arceuthobium laricis

on *Larix occidentalis*

WASHINGTON: YAKIMA CO., 5 miles E of White Pass, *Wicker* in 1962 (WSP 52731, 52734) and in 1964 (WSP 54011).

Arceuthobium microcarpum

on *Picea engelmannii*

ARIZONA: APACHE CO., 20 miles W of Eagar, *Hawksworth and Lightle 207* in 1962 (FPF); 2 miles E of Big Lake, *Hawksworth 1285* in 1970 (FPF). *COCONINO CO.*, Grand Canyon Natl. Park, North Rim, *Gill and Ellis* in 1939 (FPF 89418), and *Wicker* in 1967 (WSP 57619). *GRAHAM CO.*, Graham Mts., *Gill* in 1934 (FPF 68310 and 68240); *Ellis* in 1938 (FPF 89402); *Ellis* in 1939 (FPF 89414 and 89428); *Ellis* in 1940 (FPF 89433); *Mielke and Ellis* in 1944 (FPF 89692). *GREENLEE CO.*, Hannagan Meadows, *Lightle* in 1964 (FPF 1794); Blue Summit, *Ellis* in 1939 (FPF 89412).

on *Picea pungens*

ARIZONA: APACHE CO., 2 miles SW of Greer, *Hawksworth and Lightle 925* in 1966 (FPF).

Arceuthobium tsugense

on *Abies amabilis*

WASHINGTON: LEWIS CO., 3 miles W of White Pass, *Wicker* in 1961 (WSP 52111), in 1962 (WSP 52732, 54008), in 1963 (WSP 54009), and 1966 (FPF 2467).

on *Pinus albicaulis*

OREGON: DESCHUTES CO., 1 mile E of McKenzie Pass, *Knutson* in 1976 (FPF).

on *Tsuga heterophylla*

OREGON: BENTON CO., Marys Peak, *Knutson* in 1973 (FPF). *LINN CO.*, Sheep Creek on Highway 20, *Knutson* in 1973 (FPF).

WASHINGTON: PIERCE CO., Longmire, *Gill* in 1932 (FPF 68199). *YAKIMA CO.*, 3 miles W of White Pass, *Wicker* in 1962 (WSP 52736, 54001) in 1963 (WSP 54010), and in 1966 (FPF 2466).

on *Tsuga mertensiana*

CALIFORNIA: ALPINE CO., Ebbetts Pass, *Hawksworth and Scharpf 665* in 1964 (FPF). *SISKIYOU CO.*, Marble Mts., Kidder Creek, *Gill and Sargent* in 1932 (FPF 68180).

OREGON: JACKSON CO., 10 miles NE of Prospect, *Graham* in 1965 (FPF 2335).

Wallrothiella arceuthobii

Arceuthobium americanum

on *Pinus contorta*

IDAHO: BONNER CO., Priest Lake, *Piper 3701* in 1901 (GH).

MONTANA: MINERAL CO., 6 miles W of St. Regis, *Hawksworth and Wicker 954* in 1966 (FPF).

OREGON: LINN CO., Junction of Highways 20 and 22, near Santiam Pass, *Knutson* in 1976 (FPF).

WASHINGTON: FERRY CO., Growden, *Wicker* in 1961 (WSP 52158) and 1962 (WSP 52735).

Arceuthobium douglasii

on *Pseudotsuga menziesii*

ARIZONA: APACHE CO., 5 miles SW of Alpine, *Lightle* in 1964 (FPF 1793) and

Hawksworth and Scharpf 699 in 1964 (FPF). 3 miles NW of Maverick, *Hawksworth and Lightle 902* in 1966 (FPF). *COCHISE CO.,* Chiricahua Mts., *Gill and Ellis* in 1935 (FPF 68056); *Gill and Ellis* in 1939 (FPF 89497 and 89408). *COCONINO CO.,* Oak Creek Canyon, *Ellis* in 1939 (FPF 89504); Baker Butte, *Andrews et al.* in 1932 (FPF 89229); 3 miles E of Long Valley, *Lightle* in 1964 (FPF 1791); Rim Road 5 miles E of Sitgreaves Natl. For. boundary, *Lightle* in 1964 (FPF 1792); Mormon Lake, *Hawksworth and Lightle 913* in 1966 (FPF); 11 miles S of Chevelon R.S., *Hawksworth and Lightle 918* in 1966 (FPF). *GILA CO.,* Sierra Ancha Expt. For., *Hawksworth 44* in 1954 (FPF). *GRAHAM CO.,* Graham Mts., *Stouffer* in 1934 (FPF 68289); *Stouffer and Gill* in 1934 (FPF 68294); *Ellis* in 1938 (FPF 89403); *Ellis* in 1939 (FPF 89427), *Mielke and Ellis* in 1944 (FPF 89694 and 89698); *Hawksworth and Lightle 226* in 1962 (FPF). *GREENLEE CO.,* 47 miles S of Springerville on US 666, *Gill* in 1934 (FPF 68303). *NAVAJO CO.,* Rim Road, 6 miles E of Rt 160, *Hawksworth and Lightle 920* in 1966 (FPF). *PIMA CO.,* Santa Catalina Mts., *Gill and Ellis* in 1939 (FPF 89406 and 89501); *Gill* in 1932 (FPF 68125).

COLORADO: EL PASO CO., No. Cheyenne Canyon, *Hawksworth 538* in 1963 (FPF). *FREMONT CO.,* Phantom Canyon, 13 miles S of Victor, *Hawksworth and Laut 1335* in 1971 (FPF). *HINSDALE CO.,* 21 miles NW of Pagosa Springs, *Landgraf* in 1965 (FPF 1997). *LAS ANIMAS CO.,* 12 miles S of Stonewall Gap, *Hawksworth and Laut 1331* in 1971 (FPF). *MINERAL CO.,* 7 miles W of Wolf Creek Pass, *Hawksworth and Mathiasen 1451* in 1973 (FPF).

IDAHO: LATAH CO., 3 miles E of Viola, *Wicker* in 1959 (WSP 47614).

NEW MEXICO: BERNALILLO CO., Sandia Mts., *Long and Seay* in 1916 (FPF 21275); *Ellis* in 1939 (FPF 89505). *CATRON CO.,* Mangas Mt., *Scharpf and Hawksworth* in 1964 (FPB 98116, FPF 1733); Fox Mt., *Hawksworth and Lightle 928* in 1966 (FPF); Bearwallow Mt., *Hawksworth and Lightle 898* in 1966 (FPF). *COLFAX CO.,* 8 miles SE of Black Lake, *Lightle* in 1965 (FPF 2134). *LINCOLN CO.,* Capitan Mts., W. Capitan Mt., *Lightle* in 1966 (FPF 2490); Gallinas Mts., *Lightle and Riffle* in 1963 (FPF 1412) and *Hawksworth 1079* in 1967 (FPF); Capitan Mts., Capitan Gap, *Hawksworth and Lightle 1099* in 1968 (FPF). *OTERO CO.,* 7 miles E of Cloudcroft, *Hawksworth 1* in 1967 (FPF); Mescalero Apache Reservation; Goat Canyon, *Hawksworth* in 1952 (FPF 89992); Summit Canyon *Hawksworth 26* in 1952 (FPF) and *Hawksworth and Scharpf 694* in 1964 (FPF, FPB 98120). *SAN JUAN CO.,* 6 miles SW of Sheep Springs, *Lightle and Weiss* in 1966 (FPF 2496). *SAN MIGUEL CO.,* 15 miles E of Pecos, *Lightle* in 1963 (FPF 1308); Cowles, *Lightle* in 1965 (FPF 2129 and 2130). *SOCORRO CO.,* San Mateo Mts., *Long* in 1915 (FPF 21126). *TAOS CO.,* 1 mile W of Colfax Co. on US 64, *Lightle* in 1965 (FPF 2126). *TORRANCE CO.,* 3 miles NW of Manzano, *Riffle* in 1963 (FPF 1208). *VALENCIA CO.,* Mt. Sedgwick, *Lightle* in 1965 (FPF 1790).

OREGON: JACKSON CO., 9 miles NE of Prospect, *Graham* in 1965 (FPF 2357); 10 miles E of Butte Falls, *Graham* in 1964 (FPF 1703); 12 miles SE of Butte Falls, *Graham* in 1965 (FPF 2356). *JEFFERSON CO.,* Suttle Lake, *Knutson* in 1976 (FPF). *JOSEPHINE CO.,* 13 miles E of O'Brien, *Hawksworth and Hinds 997* in 1966 (FPF).

TEXAS: CULBERSON CO., Guadalupe Mts. Natl. Park, The Bowl, *Hawksworth and Bailey 1528* in 1975 (FPF).

WASHINGTON: FERRY CO., Lane Creek, *Wicker* in 1966 (WSP 56491).

MEXICO: COAHUILA, Sierra del Carmen, *Hawksworth and Lightle 1027* in 1967 (FPF).

DURANGO: 47 miles S of Durange on La Flor Road, *Hawksworth and Wiens 514* in 1963 (FPF).

Arceuthobium vaginatum subsp. *cryptopodum*

on *Pinus ponderosa*

NEW MEXICO: OTERO CO., Mescalero Apache Reservation, Goat Canyon, *Hawksworth* in 1952 (FPF 98511).

Hawksworth, Frank G., Ed F. Wicker, and Robert F. Scharpf. 1977. Fungal parasites of dwarf mistletoes. USDA For. Serv. Gen. Tech. Rep. RM-36, 14 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

At least eight fungi are known to parasitize dwarf mistletoe shoots in North America. Three of these (*Colletotrichum gloeosporioides*, *Cylindrocarpon gillii*, and *Wallrothiella arceuthobii*) are common and occur on most of the dwarf mistletoes in the western United States. *Pestalotia heterocornis* and *Cylindrocarpon* sp. are reported for the first time as dwarf mistletoe parasites. Although some of these fungi may decimate dwarf mistletoe shoots and fruits in certain localities in certain years, their overall role in limiting dwarf mistletoes seems to be minor.

Keywords: *Colletotrichum gloeosporioides*, *Cylindrocarpon gillii*, *Wallrothiella arceuthobii*, hyperparasites, biological control.

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Keywords: *Colletotrichum gloeosporioides*, *Cylindrocarpon gillii*, *Wallrothiella arceuthobii*, hyperparasites, biological control.

Hawksworth, Frank G., Ed F. Wicker, and Robert F. Scharpf. 1977. Fungal parasites of dwarf mistletoes. USDA For. Serv. Gen. Tech. Rep. RM-36, 14 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

At least eight fungi are known to parasitize dwarf mistletoe shoots in North America. Three of these (*Colletotrichum gloeosporioides*, *Cylindrocarpon gillii*, and *Wallrothiella arceuthobii*) are common and occur on most of the dwarf mistletoes in the western United States. *Pestalotia heterocornis* and *Cylindrocarpon* sp. are reported for the first time as dwarf mistletoe parasites. Although some of these fungi may decimate dwarf mistletoe shoots and fruits in certain localities in certain years, their overall role in limiting dwarf mistletoes seems to be minor.

Keywords: *Colletotrichum gloeosporioides*, *Cylindrocarpon gillii*, *Wallrothiella arceuthobii*, hyperparasites, biological control.


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Rocky Mountain Forest and
Range Experiment Station
U.S. Department of Agriculture
Fort Collins, Colorado 80521

Managing Aspen For Wildlife r The Southwest



USDA Forest Service
General Technical Report RM-37 April 1977

Managing Aspen For Wildlife In The Southwest

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Ninety-three percent of the existing aspen stands in the Southwest are mature or overmature, and do not have large numbers of sprouts. The typically smaller aspen stands of the region can be managed for browse production with a rotation of 20-30 years. Clearcutting and fire can produce a stand with thousands of vigorous sprouts per acre.

Keywords: *Populus tremuloides*, wildlife habitat, clearcutting, fire, browse production.

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Managing Aspen For Wildlife In The Southwest

David R. Patton and John R. Jones

Quaking aspen is an important wildlife food in the Southwest. It is available during most of the year, and provides needed protein to deer and elk when other plants are unavailable or low in nutrient value. Unless stands are regenerated by cutting or burning, aspen acreage in Arizona and New Mexico will gradually decline.

Aspen is the dominant canopy species on about 79,000 acres in Arizona (Spencer 1966) and 400,000 acres in New Mexico (Choate 1966). In the neighboring States to the north it is even more abundant. In Utah, aspen is the most widespread forest type, occupying 1,425,000 acres (Choate 1965), while Colorado has 3,135,000 acres (Miller and Choate 1964).

Factors That Affect Regeneration

Although some pistillate clones produce enormous numbers of tiny seeds, numerous observers dating back at least to Baker (1918) have stated that aspen reproduction in the West is nearly all by sprouting (suckering) from roots. Production of good seed is erratic, and highly infrequent in some areas (Baker 1918). The tiny new seedlings are very susceptible to both drying and damping off (Einspahr 1959) and establish successfully only under extremely favorable conditions (Larson 1944).

Aspen stands have a network of interconnected lateral roots (Tew et al. 1969). Suckers originate from pre-existing bud primordia on root segments usually less than 8 inches or so from the soil surface, but as deep as 12 inches. Suckering and sucker growth is suppressed by shade and by the apical dominance of the aspen canopy trees which maintain and depend on the root network (Maini and Horton 1966, Schier 1972). Suckers are usually sparse and of poor vigor beneath an intact forest canopy. Selective cutting, or fire that leaves most canopy trees alive, will sometimes result in numerous suckers. While sucker survival and growth are likely to be poor in such cases, they are sometimes fairly good (Baker 1925, Larson 1959, Smith et al. 1972).

Complete removal of a well-stocked aspen forest by fire or clearcutting can produce a stand of 30,000 to more than 100,000 vigorous suckers per acre the first summer (Baker 1925, Smith et al. 1972). If a stand is clearcut in summer, suckering may be delayed

until the following summer (Baker 1918). In either case, the number of suckers declines during subsequent years. Clearcutting an old, deteriorated, poorly stocked stand produces relatively few suckers, apparently because the network of live roots has become sparse.

Observation and limited data suggest that, when a mixed conifer stand is removed by clearcutting or fire, the resulting aspen sucker stand will probably be less dense initially than if the parent stand had been aspen. Instead of declining, sucker density is then likely to increase for several years. Maximum numbers after 4 or 5 summers (Patton and Avant 1970) may approximate those occurring when the parent stand is aspen. On Escudilla Mountain in Arizona, where fire destroyed extensive mixed conifer forest, many of the resulting aspen stands still had 6,000 to 10,000 or more stems per acre at age 22.

Suckers free of overhead domination grow rapidly. Their leafy crowns are out of reach of browsing deer and elk after 6 to 8 years and commonly sooner (Patton and Avant 1970, Smith et al. 1972). On the other hand, repeated heavy browsing over the first several summers, especially by sheep, can eliminate a well-stocked sucker stand, leaving the parent root network depleted and unable to generate more suckers (Smith et al. 1972). Destruction of an initially well-stocked, vigorous sucker stand by game and cattle is unlikely (Smith et al. 1972), unless an excessive number of animals is concentrated on a small area.



Aspen sprouts 6 years following a fire — nearly out of reach as a food supply for deer and elk.

Beyond the juvenile stage, the major killers of aspen are diseases. Several canker diseases take a gradual toll of aspen. In areas of exceptionally heavy elk use, scars from elk feeding on the bark result in numerous canker infections. Associated browsing can eliminate suckers from the understory. If overuse continues, the stand will be replaced by nonforest vegetation (Hinds and Krebill 1974).

In some areas, outbreaks of the western tent caterpillar (*Malacosoma californicum* Packard, formerly *M. fragile* Stretch) defoliate aspen for several consecutive years, severely reducing diameter growth (Jones 1966) and frequently causing extensive top dieback (Stelzer 1968). Outbreaks eventually collapse, but some aspen stands are essentially destroyed before they do (Stelzer 1968). Because subsequent suckering is initially sparse and weak, animal use may completely eliminate aspen from some sites.

Extensive sampling of overmature aspen stands indicated that 200 years is near the maximum age for aspen stands in the Southwest. Only two stands in southern Colorado near the New Mexico boundary were over 200 years, and the oldest stand in New Mexico was 190.

Mature aspen forests often have an understory of shade-tolerant conifers. Without a hot fire or heavy cutting, elimination of the aspen overstory will leave the site dominated by conifers with only a scattering of aspen. If the new stand is Engelmann spruce and corkbark fir, aspen may be entirely or nearly eliminated from the site unless something drastic happens to reestablish it.



Conifers coming in under a pole-sized aspen stand.

Beneath other aspen canopies there has been little or no coniferous invasion, either because there is little or no need of shade-tolerant conifers or because the environment is too severe for their abundant establishment. The gradual disintegration of such aspen stands, where fire and cutting are excluded, is accompanied by scattered aspen suckering. Low sucker density and the slow growth of suckers beneath the partial canopy makes them particularly susceptible to being browsed back. When the last of the present overstory aspen dies on some of these sites, the dominant vegetation likely will be grass. Where aspen suckers have become established beneath an old stand and have outgrown browsing, the new stand will probably be poorly stocked.

Therefore, whether the aspen is being succeeded by conifers or not, continued exclusion of fire and cutting will gradually result in the gross reduction of aspen. It is important to realize that most aspen stands in the Southwest are already mature or overmature: 93% of aspen acreage is in the pole or sawtimber classes (Choate 1966, Spencer 1966).

Management and Stand Analysis

Aspen does not usually form large stands in the Southwest. Small stands are generally associated with large stands of conifers. Because of this characteristic, management of aspen for deer and elk should be aimed at providing large amounts of leaves and twigs for food, not primary cover. The necessary cover would be located within the adjacent pine, spruce, or fir vegetation.

Either extremely long or short rotations may be undesirable for management of aspen for sprout and foliage production. A long rotation would probably reduce benefits because of decreased sprout production by deteriorating stands. Too short a rotation might result in reduced sprout production from a loss of vigor in a stand cut too frequently. A rotation of around 20 to 30 years for browse production seems reasonable. After 5 years the stems and leaves are growing out of reach of browsing animals and there is little new sprouting (Patton 1970).

The next problem in managing aspen is a decision on when and how much to maintain or produce. Only 5% of the aspen acreage in Arizona is in the seedling and sapling age class; 8% of the acreage in New Mexico is in this class. The two States combined have 479,000 acres in aspen, 7% of it in the seedling and sapling stage. Although how much is needed by wildlife is pure speculation, the present aspen acreage should at least be maintained or increased.

Enough ecological data are available so that managers can purposefully plan for the establishment of new acreage or regeneration of present stands to maintain browse continuity. The amount of acreage may not be as important as having a good distribution of aspen in the several coniferous forest types. This distribution takes

planning and coordination with the other resource functions of timber, range, watershed, and recreation.

Any manager of aspen for wildlife will need information on acreage, ages, successional stages, and stand conditions. He should consider aspen in predominantly coniferous stands as well as stands with more or less pure aspen canopies. Both types of stands can be delineated easily on aerial photographs and shown on 2-inch-per-mile base maps in units as small as 10 acres. Stands then should be examined on the ground well in advance to permit realistic management planning.

A number of considerations may influence what should be done with a stand. Although it is not feasible here to consider all the possible combinations of factors that need to be considered, the nine situations described provide alternative examples.

In Conifer-Aspen Mixtures

1. Patches may be clearcut to stimulate aspen suckering, with the primary purpose of browse production.
2. In some stands, some patches of conifers are heavily infected with dwarf mistletoe, and may be clearcut as a sanitation measure. Aspen suckers are likely to occupy such clearcut patches. Aspen browse production is only a secondary consideration in such situations.
3. The stand may be reasonably healthy and productive, and managed for continuing production of coniferous timber with aspen as only a minor and incidental stand constituent. Aspen suckers on landings and in other openings will provide limited browse and will tend to maintain aspen presence on the site.

Aspen Canopies With Coniferous Understories

4. The aspen canopy trees may be healthy and the conifers cut to increase herbage production. (Eventually it will be necessary to reproduce the aspen.)
5. Conifers can outproduce aspen on many sites. On such sites the aspen may be cut to release the conifers. The operation will produce gaps in the coniferous understory that will often be filled by aspen suckers, producing some browse and maintaining aspen presence on the site.
6. Aspen can outproduce conifers on some sites. The aspen may be clearcut and the understory removed, maintaining aspen dominance and producing abundant browse.

Aspen Stand With No Coniferous Understory

7. A roadside stand that is becoming decadent may have particular esthetic value as high forest. Small patches, totaling about one-

third of the stand, may be clearcut, leaving the immediate roadside largely uncut. The rest may be clearcut after another 15 years, except for groves of old growth left here and there along the road to go out gradually.

8. Some mature stands have no special esthetic value and grow on mediocre or poor sites. Twenty percent of the stand may be clearcut every 4 years to provide a continuous supply of aspen forage for deer and elk.

Decadent Aspen Stands

9. Aspen snags and decadent trees are needed to maintain bird species diversity and abundance. In logging operations some of these types of trees should be left as homes and feeding sites for cavity-nesting and other birds.



Aspen snags provide homes for cavity-nesting birds (photo courtesy of U.S. Fish and Wildlife Service).

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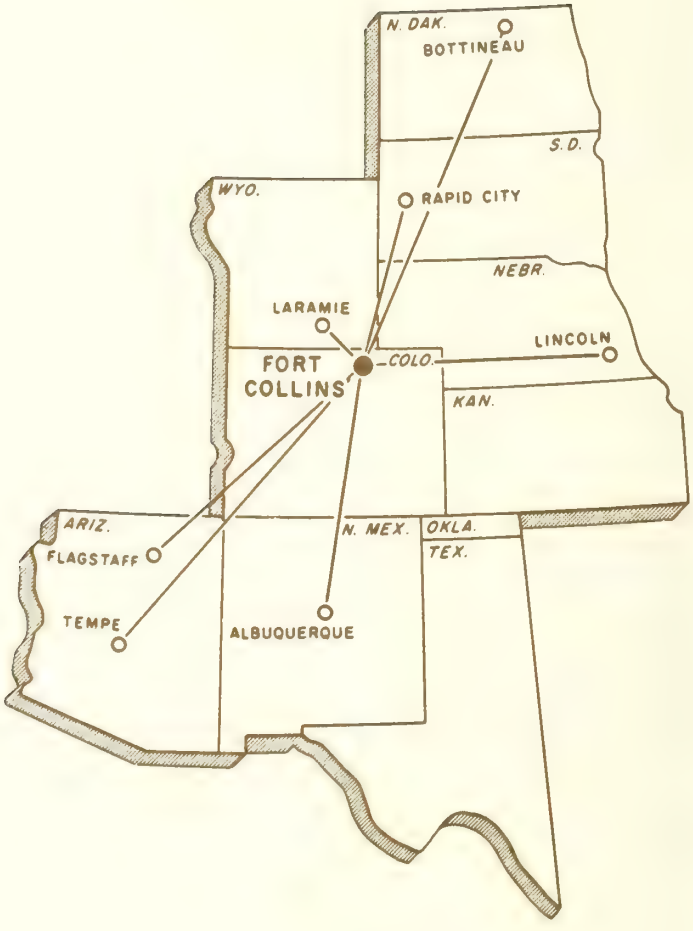
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Keywords: *Populus tremuloides*, wildlife habitat, clearcutting, fire, browse production.

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Birds and Mammals of Manitou Experimental Forest, Colorado



Abstract

Morris, Meredith J., Vincent H. Reid, Richard E. Pillmore, and Mary C. Hammer. 1977. Birds and mammals of Manitou Experimental Forest, Colorado. USDA For. Serv. Gen. Tech. Rep. RM-38, 17 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Seasonal occurrence, relative abundance, and habitat preference are listed for 90 bird and 41 mammal species that can be found at Manitou Experimental Forest. An annotated list is given also for an additional 70 casual or accidental bird species. Manitou Experimental Forest is located near Colorado Springs in the montane zone of the Colorado Front Range.

Keywords: Birds, mammals, wildlife habitat.

USDA Forest Service
General Technical Report RM-38

July 1977



Birds and Mammals of Manitou Experimental Forest, Colorado

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Birds and Mammals of Manitou Experimental Forest, Colorado

Meredith J. Morris, Vincent H. Reid,
Richard E. Pillmore, and Mary C. Hammer

The Manitou Experimental Forest is located about 28 mi northwest of Colorado Springs, Colorado, on State Highway 67, north of Woodland Park (fig. 1). The Experimental Forest is in a valley known as Manitou Park which is paralleled by two north-south mountain ranges, the Rampart Range on the east and West Creek Range on the west. The valley is drained by Trout Creek, a tributary of the South Platte River. Elevations vary from about 7,600 ft (2,320 m) to 9,400 ft (2,860 m). The Forest contains about 26 mi² (6,730 ha) with some interspersed non-Federal lands.

Several steep-walled canyons occur in the rough eastern part. From south to north, these drainages are Johns Gulch, Hotel Gulch, White Spruce Gulch, and Missouri Gulch. Some recreational areas have been established in the southwest part of the Experimental Forest. Painted Rocks Campground and Camp Elim, a church camp, are located on the West Creek Road. Manitou Picnic Ground and Colorado Campground are situated beside Manitou Lake, a reservoir on Trout Creek.

In the West Creek drainages, southwest of and adjacent to the Experimental Forest, bird censuses were conducted from 1968 through 1972 by the Denver Wildlife Research Center, U.S. Fish and Wildlife Service, in cooperation with the Pacific Southwest Forest and Range Experiment Station in an experimental study of forest insecticides. Information from these censuses is applicable to comparable areas on the Manitou Experimental Forest. The West Creek drainages include Manchester, Phantom, and Trail Creeks, and Long, Stone, and Spruce Gulches.

Manitou Park's long and interesting history indicates fur trapping and trading in the early 1800's as the white man's first activity in the area. By the late 1800's, mining had become the main reason for occupancy and use of the pine lands. Commercial logging of ponderosa pine[4] began about 1860. Pine timber furnished mine props, railroad ties, building lumber, fuel, and charcoal. No large merchantable stands of pine remained in the area after 1900.

[4]*Common and scientific names of plants (Nickerson, Brink, and Feddema 1976) are listed at the end of this report.*



Livestock grazing was quite heavy in the early days and reached a peak in the 1880-90 period. Cultivated crops, including hay and potatoes, were in high demand. After 1900, farming and ranching activities began to decline, and by the midthirties, all the farmlands had been abandoned. Although ranching is still being practiced, cattle numbers are far below what they once were.

Manitou Park was once a well-known resort. Dr. William A. Bell from London, England, built the first hotel about 1875 near the present Experimental Forest headquarters. Fire destroyed this hotel in 1886. A second hotel opened in 1894, and burned in 1899. Some cottages were built later as well as the third hotel which burned in 1925.

In 1905, about 12,000 acres (4,860 ha) of land were given to Colorado College by Dr. Bell and General William J. Palmer, the founder of Colorado Springs. This tract, known as the Reserve of the School of Forestry, was used as an outdoor campus by the first forestry school established west of the Mississippi River. Colorado College operated its Forestry School until 1934. In 1937, the Colorado College tract, plus several thousand acres of croplands purchased by the Resettlement Administration were transferred to the Forest Service to form the Manitou Experimental Forest.

Vegetation

The region in which the Experimental Forest is located has been so disturbed by fires, insect and disease attacks, and past land use that one would be hard pressed to find a single acre of primeval forest. These impacts, plus highly variable site conditions, have resulted in a complex mosaic of plant communities, all of which are in some successional stage below the climax. These communities will be briefly described because most of them provide unique habitats for certain species of birds and mammals.

Ponderosa Pine

Several silvicultural treatments have been or are being applied to improve the ponderosa pine stands at Manitou. These treatments include thinning, improvement cutting, clearcutting for dwarf mistletoe control, and shelterwood and group selection cutting (Myers 1974). All snags were removed in the first timber harvest, but in later harvests snags were marked with metal signs prior to cutting to reserve them as wildlife trees.

Much of the pine forest, particularly in the harvested areas and drier sites, presents an open, parklike appearance. Depending on the soil and tree density, the understory vegetation is quite variable in composition. Where grasses are dominant, the main species are Arizona fescue and mountain muhly and, to a lesser degree, blue grama and little bluestem. If shrubs are present, the dominants are true mountainmahogany, common juniper, bearberry, and, in some areas, skunkbush sumac. Forbs such as stemless hymenoxys, hairy goldaster, and Fremont geranium may be present.

Douglas-fir

Stands of Douglas-fir are found on north slopes in moderately steep parts of the Experimental Forest. Site conditions are more mesic or wetter than on the south slopes where ponderosa pine usually occurs. The understory in the Douglas-fir stands may include RockyMountain maple and mountain ninebark in substantial amounts, or the two species may be completely absent. Other shrubs occurring in the stands are RockyMountain clematis and, on very steep slopes, cliff jamesia. Associated forb species are European strawberry and yellowdot saxifrage.

Lodgepole Pine

Lodgepole pine stands are found in the upper drainages and along the Rampart Range in the northeast part of the Experimental Forest. Some stands contain very little understory vegetation except for a few scattered plants of bearberry and common juniper. Other stands have a good understory of Rocky Mountain whortleberry plus a variety of herbaceous species.

Mixed Conifer

Interspersed throughout the Experimental Forest are mixed stands of coniferous species in vary-

ing combinations and proportions. Included in these mixtures are ponderosa pine, Douglas-fir, lodgepole pine, and Engelmann spruce. A few blue spruce can also be found, as well as quaking aspen, a deciduous species. These mixed stands probably represent ecotones between the main types, or successional stages due to some kind of disturbance. Examples of some of the species combinations are ponderosa pine-Douglas-fir, Engelmann spruce-Douglas-fir, lodgepole pine-Douglas-fir, and ponderosa pine-lodgepole pine-Douglas-fir. The understory vegetation is extremely variable. Wax currant, shrubby cinquefoil, and a considerable number of other shrub and herbaceous species may be present.

Quaking Aspen

Although aspen is usually associated with other tree species on the Experimental Forest, there are a few areas where it is the dominant. The aspen in these stands is usually of rather poor quality, but the understory is highly diverse and very luxuriant. Some of the more common plants include bearberry, common juniper, rose, geranium, northern bedstraw, fleabane, aster, brome, and sedge.

Open Grassland and Meadow

On the valley floor and scattered over the Forest are open grassland and meadow areas that vary from one to many acres in size. Some of these communities are natural, but some are obviously the product of clearing and cultivation. Of the four species, Arizona fescue, mountain muhly, blue grama, or Kentucky bluegrass, one is usually the dominant in the grasslands, but sleepygrass, pussytoes, butter-and-eggs toadflax, or fringed sagebrush may be locally dominant. The Forest Service has seeded introduced species on several areas at Manitou that had formerly been cultivated. These included big bluegrass, Russian wildrye, smooth brome, and wheatgrasses. Native plant species are invading the seeded areas, however, and may eventually replace the introduced species.

Meadows are most extensive along Trout Creek, but some small ones may also be found in the upper drainages. Meadows, because of a higher water table, are much more productive than the grasslands. The dominant plants are mostly sedges and rushes (mainly Baltic rush) with some wheatgrasses, northern reedgrass, Kentucky bluegrass, and other species present.

Riparian

The most conspicuous example of a riparian community at Manitou is the discontinuous band of willows along Trout Creek. The ground cover is mainly sedges, rushes, and some Kentucky bluegrass with smooth horsetail being locally abundant. This community is regularly being modified by beaver activity, and irregularly by intense summer storms.

Narrow belts of riparian vegetation run generally eastward up through the drainages to the Rampart Range. The plant communities are shrub or mixed tree-shrub types; the trees are the same species as found elsewhere on the Experimental Forest. Shrubs occurring in these communities are thinleaf alder, water birch, common chokecherry, and willow. The vegetation in this type is generally very luxuriant and highly diverse.

Aquatic habitats include Manitou Lake and the perennial streams in Hotel Gulch, Missouri Gulch, and Trout Creek. Numerous beaver ponds are present on the Experimental Forest as well as in the West Creek drainages.

Birds

The list of bird species occurring at Manitou Experimental Forest is divided into two sections (table 1). All common and scientific names of birds follow the Check-list of North American Birds, fifth edition (American Ornithologists' Union 1957) as amended by the Thirty-second Supplement to the Check-list (American Ornithologists' Union 1973). The first part shows the seasonal occurrence and relative abundance of those species that are found on a more or less regular basis. Periodic variations in food supplies, regional or global climatic disturbances, or possibly other factors may cause marked fluctuations in occurrence and abundance of some species, however. If applicable, preferred habitats or plant communities are given for each species as well as some other helpful notes. The second part lists casual or accidental species, that is, those that have been observed only once to a few times. Sighting dates and initials of observers are given as well as citations for those reported in the literature.

Table 1.—Birds observed at the Manitou Experimental Forest, Colorado, separated into (1) yearlong and seasonal occurrences with relative abundance; and (2) casual or accidental occurrences with notes on date observed and observer's initials. In suitable habitat, one may expect to find this bird:

 at least 75% of the time;  between 25% and 75% of the time;

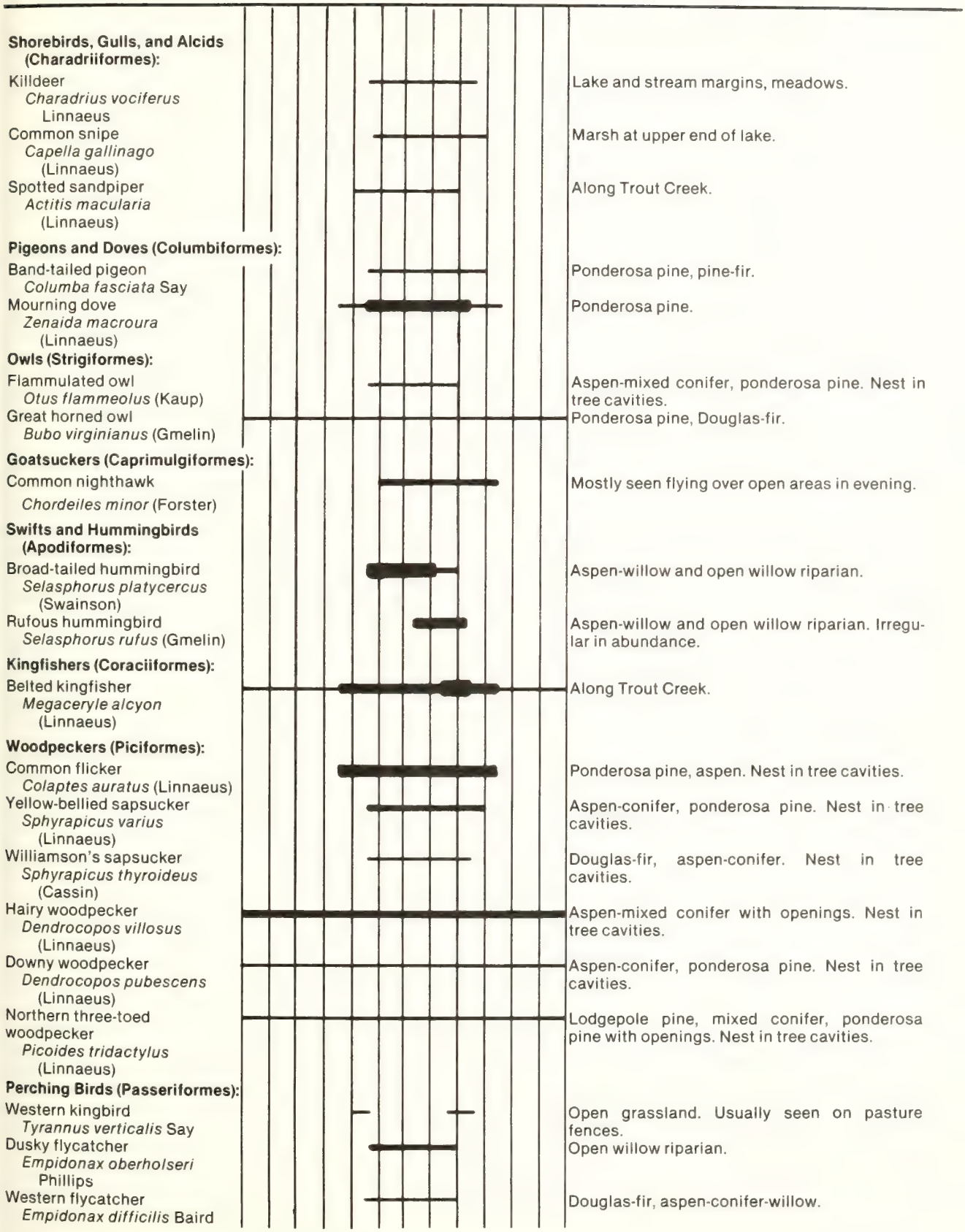
 less than 25% of the time.

(Length of line indicates average arrival and departure dates)

Initials of observers:

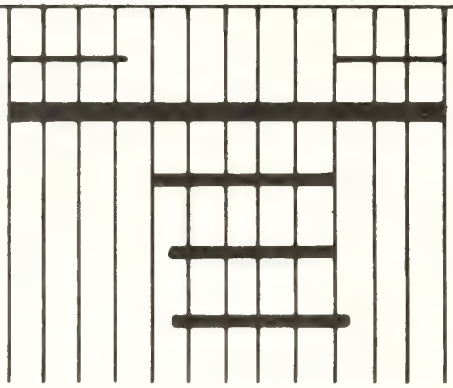
A.A.S.—	Aiken Audubon Society	JVKW—	J. V. K. Wagar
AC—	Alene Catlett	MCH—	Mary C. Hammer
BK—	Beverly Knott	MJM—	Meredith J. Morris
CAM—	Clifford A. Myers	MS—	Marie Shier
DAB—	Dominic A. Bartol, Jr. (Mr. and Mrs.)	MSs—	Mahlon Speers
FGH—	Frank G. Hawksworth	POC—	Pat O. Currie
FJH—	Frederick J. Hermann	REP—	Richard E. Pillmore
FLH—	Frederick L. Hammer	RGB—	Richard G. Beidleman
GRS—	George R. Shier	SM—	Sadie Morrison
GWH—	George W. Hudler	ST—	Steve Taliferro
HAW—	Howard A. Winkler	SWG—	Samuel W. Gadd
HEM—	Harley E. Metz	WAD—	William A. Davis
HLG—	Howard L. Gary	WRM—	Walter R. Mark

Species	J	F	M	A	M	J	J	A	S	O	N	D	Notes
	Yearlong or Seasonal:												
Waterfowl (Anseriformes):													
Mallard *Anas platyrhynchos* Linnaeus													Manitou Lake and beaver ponds.
Green-winged teal *Anas crecca* Linnaeus													Manitou Lake and beaver ponds. Breeding records from West Creek drainages only.
Blue-winged teal *Anas discors* Linnaeus													Manitou Lake and beaver ponds. Two families observed on Trout Creek from June 1–July 20, 1976.
Cinnamon teal *Anas cyanoptera* Vieillot													Manitou Lake and beaver ponds. Irregular in occurrence.
Vultures, Hawks, and Falcons (Falconiformes):													
Turkey vulture *Cathartes aura* (Linnaeus)													Frequently seen soaring overhead.
Goshawk *Accipiter gentilis* (Linnaeus)													Ponderosa pine.
Sharp-shinned hawk *Accipiter striatus* Vieillot													Dense pine-fir.
Cooper's hawk *Accipiter cooperii* (Bonaparte)													Ponderosa pine, Douglas-fir.
Red-tailed hawk *Buteo jamaicensis* (Gmelin)													Ponderosa pine and pine-fir near open grassland.
Marsh hawk *Circus cyaneus* (Linnaeus)													Meadow and open grassland near Trout Creek.
American kestrel *Falco sparverius* (Linnaeus)													Open grassland, often seen along highway. Nest in tree cavities. More numerous in late summer.
Gallinaceous Birds (Galliformes):													
Blue grouse *Dendragapus obscurus* (Say)													Ponderosa pine, Douglas-fir.
Turkey *Meleagris gallopavo* Linnaeus													Aspen-mixed conifer, ponderosa pine.


Species
J F M A M J J A S O N D
Notes
Shorebirds, Gulls, and Alcids (Charadriiformes):
Killdeer
Charadrius vociferus Linnaeus
Lake and stream margins, meadows.
Common snipe
Capella gallinago (Linnaeus)
Marsh at upper end of lake.
Spotted sandpiper
Actitis macularia (Linnaeus)
Along Trout Creek.
Pigeons and Doves (Columbiformes):
Band-tailed pigeon
Columba fasciata Say
Ponderosa pine, pine-fir.
Mourning dove
Zenaida macroura (Linnaeus)
Ponderosa pine.
Owls (Strigiformes):
Flammulated owl
Otus flammeolus (Kaup)
Aspen-mixed conifer, ponderosa pine. Nest in tree cavities.
Great horned owl
Bubo virginianus (Gmelin)
Ponderosa pine, Douglas-fir.
Goatsuckers (Caprimulgiformes):
Common nighthawk
Chordeiles minor (Forster)
Mostly seen flying over open areas in evening.
Swifts and Hummingbirds (Apodiformes):
Broad-tailed hummingbird
Selasphorus platycercus (Swainson)
Aspen-willow and open willow riparian.
Rufous hummingbird
Selasphorus rufus (Gmelin)
Aspen-willow and open willow riparian. Irregular in abundance.
Kingfishers (Coraciiformes):
Belted kingfisher
Megaceryle alcyon (Linnaeus)
Along Trout Creek.
Woodpeckers (Piciformes):
Common flicker
Colaptes auratus (Linnaeus)
Ponderosa pine, aspen. Nest in tree cavities.
Yellow-bellied sapsucker
Sphyrapicus varius (Linnaeus)
Aspen-conifer, ponderosa pine. Nest in tree cavities.
Williamson's sapsucker
Sphyrapicus thyroideus (Cassin)
Douglas-fir, aspen-conifer. Nest in tree cavities.
Hairy woodpecker
Dendrocopos villosus (Linnaeus)
Aspen-mixed conifer with openings. Nest in tree cavities.
Downy woodpecker
Dendrocopos pubescens (Linnaeus)
Aspen-conifer, ponderosa pine. Nest in tree cavities.
Northern three-toed woodpecker
Picoides tridactylus (Linnaeus)
Lodgepole pine, mixed conifer, ponderosa pine with openings. Nest in tree cavities.
Perching Birds (Passeriformes):
Western kingbird
Tyrannus verticalis Say
Open grassland. Usually seen on pasture fences.
Dusky flycatcher
Empidonax oberholseri Phillips
Open willow riparian.
Western flycatcher
Empidonax difficilis Baird
Douglas-fir, aspen-conifer-willow.

Species	J F M A M J J A S O N D	Notes
Western wood pewee *Contopus sordidulus* Sclater		Aspen-conifer-willow riparian, open pine.
Olive-sided flycatcher *Nuttallornis borealis* (Swainson)		Ponderosa pine, pine-fir.
Horned lark *Eremophila alpestris* (Linnaeus)		Open grassland and meadow.
Violet-green swallow *Tachycineta thalassina* (Swainson)		Aspen-conifer-willow and open willow riparian. Nest in tree cavities.
Tree swallow *Iridoprocne bicolor* (Vieillot)		Aspen-conifer-willow and open willow riparian. Nest in tree cavities.
Rough-winged swallow *Stelgidopteryx ruficollis* (Vieillot)		Along Trout Creek.
Barn swallow *Hirundo rustica* Linnaeus		Along Trout Creek and around headquarters area.
Gray jay *Perisoreus canadensis* (Linnaeus)		Cosmopolitan at higher elevations. More common in West Creek area than at Manitou.
Steller's jay *Cyanocitta stelleri* (Gmelin)		Cosmopolitan, slight preference for aspen.
Black-billed magpie *Pica pica* (Linnaeus)		Cosmopolitan but usually can be seen in open areas along Trout Creek.
Common raven *Corvus corax* Linnaeus		Cosmopolitan.
Common crow *Corvus brachyrhynchos* Brehm		Meadow and open grassland. Occasionally do not winter.
Clark's nutcracker *Nucifraga columbiana* (Wilson)		Ponderosa pine. Irregular in occurrence and abundance.
Black-capped chickadee *Parus atricapillus* Linnaeus		Aspen groves and riparian. Nest in tree cavities at lower elevations.
Mountain chickadee *Parus gambeli* Ridgway		Cosmopolitan, slight preference for aspen. Nest in tree cavities.
White-breasted nuthatch *Sitta carolinensis* Latham		Ponderosa pine, Douglas-fir. Nest in tree cavities.
Red-breasted nuthatch *Sitta canadenis* Linnaeus		Douglas-fir. Nest in tree cavities. Irregular in occurrence and abundance.
Pygmy nuthatch *Sitta pygmaea* Vigors		Ponderosa pine, aspen. Nest in tree cavities.
Brown creeper *Certhia familiaris* Linnaeus		Douglas-fir. Nest in tree cavities.
House wren *Troglodytes aedon* Vieillot		Aspen conifer-willow riparian. Nest in tree cavities.
Mockingbird *Mimus polyglottos* (Linnaeus)		Open grassland and roadsides.
Gray catbird *Dumetella carolinensis* (Linnaeus)		Open willow riparian.
American robin *Turdus migratorius* Linnaeus		Cosmopolitan, slight preference for aspen. Occasionally winter.
Hermit thrush *Catharus guttatus* (Pallas)		Mixed spruce-fir-pine forest. More common in West Creek area than at Manitou.
Western bluebird *Sialia mexicana* Swainson		Aspen-conifer-willow near open grassland. Nest in tree cavities.
Mountain bluebird *Sialia currucoides* (Bechstein)		Ponderosa pine and aspen near open grassland. Nest in tree cavities.
Townsend's solitaire *Myadestes townsendi* (Audubon)		Ponderosa pine, aspen-conifer-willow.

Species	J F M A M J J A S O N D	Notes
Golden-crowned kinglet *Regulus satrapa* Lichtenstein		Aspen-conifer-willow with openings. Usually nest in Engelmann spruce. Slightly erratic.
Ruby-crowned kinglet *Regulus calendula* (Linnaeus)		Aspen-conifer-willow and mixed conifer-aspen with openings.
Northern shrike *Lanius excubitor* Linnaeus		Open grassland. Usually seen on pasture fences.
Loggerhead shrike *Lanius ludovicianus* Linnaeus		Open grassland. Usually seen on pasture fences.
Starling *Sturnus vulgaris* Linnaeus		Meadow and open grassland near water. Irregular in occurrence.
Warbling vireo *Vireo gilvus* (Vieillot)		Aspen-conifer-willow riparian.
Yellow warbler *Dendroica petechia* (Linnaeus)		Open willow riparian. Irregular in occurrence.
Yellow-rumped warbler *Dendroica coronata* (Linnaeus)		Aspen-conifer-willow riparian, pine-fir forests.
MacGillivray's warbler *Oporornis tolmiei* (Townsend)		Aspen-conifer-willow riparian.
Common yellowthroat *Geothlypis trichas* (Linnaeus)		Open willow riparian.
Wilson's warbler *Wilsonia pusilla* (Wilson)		Open willow and aspen-conifer-willow riparian.
Western meadowlark *Sturnella neglecta* Audubon		Open grassland and meadow.
Red-winged blackbird *Agelaius phoeniceus* (Linnaeus)		Marshes and open willow riparian.
Brewer's blackbird *Euphagus cyanocephalus* (Wagler)		Open ponderosa pine and grassland.
Brown-headed cowbird *Molothrus ater* (Boddaert)		Open grassland and meadow. Irregular in occurrence and abundance.
Western tanager *Piranga ludoviciana* (Wilson)		Open ridges in pine-fir forest.
Black-headed grosbeak *Pheucticus melanocephalus* (Swainson)		Pine-fir-aspen. Irregular.
Cassin's finch *Carpodacus cassinii* Baird		Open ponderosa pine. Irregular in occurrence and abundance.
Pine siskin *Spinus pinus* (Wilson)		Douglas-fir, mixed conifer-aspen. Irregular in occurrence and abundance.
Red crossbill *Loxia curvirostra* Linnaeus		Mixed conifer-aspen, ponderosa pine. Irregular in occurrence and abundance.
Green-tailed towhee *Chlorura chlorura* (Audubon)		Open willow and aspen-conifer-willow riparian.
Lark bunting *Calamospiza melanocorys* Stejneger		Open grassland and meadow. Not present until July in some years.
Savannah sparrow *Passerculus sandwichensis* (Gmelin)		Open willow riparian and meadow.
Vesper sparrow *Pooecetus gramineus* (Gmelin)		Open grassland.
Lark sparrow *Chondestes grammacus* (Say)		Open grassland with scattered shrubs. Irregular.

Species	J F M A M J J A S O N D	Notes
Dark-eyed junco *Junco hyemalis* (Linnaeus)		Pine-shrub and riparian, usually in protected sites.
Gray-headed junco *Junco caniceps* (Woodhouse)		Aspen-conifer-willow, widespread near edges. Often nest in Arizona fescue clumps (Winternitz 1973).
Chipping sparrow *Spizella passerina* (Bechstein)		Ponderosa pine and pine-fir around forest openings. Occasionally winter.
Lincoln's sparrow *Melospiza lincolnii* (Audubon)		Open willow and aspen-conifer-willow riparian. Nest in willow thickets.
Song sparrow *Melospiza melodia* (Wilson)		Open willow and aspen-conifer-willow riparian. Nest in willow thickets.

Casual or Accidental:

Grebes (Podicipediformes):

Western grebe
Aechmophorus occidentalis (Lawrence)
Pied-billed grebe
Podilymbus podiceps (Linnaeus)

Observed at Manitou Lake on May 22, 1971, by FJH. Four were seen at the lake on Apr. 29, 1974, by POC, FGH, and CAM.
One was seen on Manitou Lake on Oct. 13, 1971, by POC and MJM. Observed at the lake during the period of Apr. 25 through May 13, 1974, by POC, FGH, MJM, and CAM. One was seen on a beaver pond on Oct. 21, 1975, by MJM.

Herons and Allies (Ciconiiformes):

Great blue heron
Ardea herodias Linnaeus

One was observed at Manitou Lake on Sept. 10, 1971, by MJM and CAM. Seen at the lake during the period of Sept. 6-10, 1975, by FGH, GWH, and MJM. Two were observed by HLG and GWH at Manitou Lake on July 23-26, 1976.

White-faced ibis
Plegadis chihi (Vieillot)

One was seen at the upper end of Manitou Lake on Sept. 9, 1975, by FGH, GWH, and MJM; another was seen in the same area on Apr. 29, 1976, by MJM.

Waterfowl (Anseriformes):

Canada goose
Branta canadensis (Linnaeus)

Seen on one or two occasions during fall migration by POC. Observed on May 22, 1971, by FJH.

Gadwall
Anas strepera Linnaeus

Observed on Trout Creek on May 22, 1971, by FJH and on June 9, 1971, by MJM and CAM. Seen on Aug. 30, 1973, by POC and HEM.

Pintail
Anas acuta Linnaeus

Several were seen on Manitou Lake on Sept. 9, 1975, by FGH and MJM.

American wigeon
Anas americana (Gmelin)

One was seen on Trail Creek on May 16, 1969, by REP. Observed at Manitou Lake on May 15, 1973, by POC and CAM.

Northern shoveler
Anas clypeata (Linnaeus)

Two were seen on a beaver pond on Sept. 7, 1971, by HEM. On Apr. 29, 1974, at Manitou Lake, 12 were observed by POC, FGH, and CAM. A male was observed at the lake June 5-12, 1976, by GWH.

Redhead
Aythya americana (Eyton)

Two were seen on Manitou Lake on Oct. 13, 1971, by POC and MJM.

Lesser scaup
Aythya affinis (Eyton)

Observed at Manitou Lake on Apr. 29, 1974, by POC, FGH, and CAM. A pair were observed at the lake June 5-12, 1976, by GWH.

Bufflehead
Bucephala albeola (Linnaeus)

Four pairs were seen on Manitou Lake on Apr. 29, 1974, by POC, FGH, and CAM, and two were observed on May 13, 1974, by CAM.

Vultures, Hawks, and Falcons (Falconiformes):

Swallow-tailed kite
Elanoides forficatus (Linnaeus)

One was killed in Manitou Park and taken to Charles E. Aiken in Aug. 1877 (Sclater 1912).

Species	Notes
Swainson's hawk *Buteo swainsoni* Bonaparte	One was observed near West Creek on June 4, 1969, by REP.
Golden eagle *Aquila chrysaetos* (Linnaeus)	One was seen at Manitou on Sept. 19, 1969, by POC. One was also seen in the West Creek area on Sept. 20, 1969, by REP. One observed on July 22, 1975, by POC.
Merlin *Falco columbarius* Linnaeus	Reported near Manitou Lake on July 27, 1972, by FGH and WRM. Two were seen near Trout Creek on Apr. 17, 1974, by POC and CAM, and one was seen in the same area on May 13, 1974, by CAM. Two were observed near the highway on Sept. 10, 1975, by FGH and MJM.
Cranes and Allies (Gruiformes):	
Sandhill crane *Grus canadensis* (Linnaeus)	About 200 were seen by JVKW in the fall of 1930 in meadow west of Colorado Campground.
Virginia Rail *Rallus limicola* Vieillot	One was observed on July 25, 1972, by FGH at the upper end of Manitou Lake. Two were seen on June 16, 1973, by members of A.A.S. One was seen near the lake on May 22, 1974, by RGB and MJM.
Sora *Porzana carolina* (Linnaeus)	Reported on May 22, 1971, by FJH, on May 23, 1974, by MJM, and July 16, 1974, by CAM. All observations were at upper end of Manitou Lake.
American coot *Fulica americana* Gmelin	Observed on Apr. 29, 1974, by POC, FGH, and CAM
Shorebirds, Gulls, and Alcids (Charadriiformes):	
Semipalmated sandpiper *Calidris pusilla* (Linnaeus)	Observed on Trout Creek on June 9, 1971, by POC and CAM.
Stilt sandpiper *Micropalama himantopus* (Bonaparte)	Reported at Manitou Lake on Apr. 29, 1974, by POC, FGH, and CAM.
American avocet *Recurvirostra americana* Gmelin	One was seen on a beaver pond on Trout Creek on May 14, 1970, by MJM.
Owls (Strigiformes):	
Long-eared owl *Asio otus* (Linnaeus)	One was seen near Phantom Creek on June 19, 1969, by REP, and another in Missouri Gulch on Sept. 29, 1971, by MJM.
Saw-whet owl *Aegolius acadicus* (Gmelin)	One was caught in a mist net in Johns Gulch on Aug. 26, 1974, by GWH.
Swifts and Hummingbirds (Apodiformes):	
Black-chinned hummingbird *Archilochus alexandri* (Bourcier and Mulsant)	One was observed at the head of Spruce Gulch on June 20, 1970, by REP.
Calliope hummingbird *Stellula calliope* (Gould)	One was seen in the headquarters area in July 1968 by MCH, and one was caught in a mist net near West Creek on July 16, 1968, by REP.
Perching Birds (Passeriformes):	
Eastern kingbird *Tyrannus tyrannus* (Linnaeus)	Large group observed by MCH on May 18, 1967, in open grassland north of headquarters. Seen along highway on July 25, 1972, by FGH, and on Sept. 10, 1975, by FGH and MJM.
Cassin's kingbird *Tyrannus vociferans* Swainson	One observed near Painted Rocks Campground on Sept. 10, 1971, by MJM and REP.

Species	Notes
Scissor-tailed flycatcher *Muscivora forficata* (Gmelin)	One was seen on June 3, 1969, by FLH and ST on a pasture fence east of Manitou Lake.
Say's phoebe *Sayornis saya* (Bonaparte)	One was seen near Phantom Creek in 1969 by REP. One was observed in a pasture on Aug. 24, 1971, by CAM and another near Manitou Lake on Apr. 30, 1974, by POC, FGH, and CAM.
Willow flycatcher *Empidonax traillii* (Audubon)	One was observed in Long Gulch on May 26, 1969, by REP. One was caught in a mist net on July 16, 1969, in Long Gulch and another on June 16, 1970. One was captured near Phantom Creek on June 2, 1971, and another near West Creek on June 13, 1972. Observed near Trout Creek on June 5, 1973, by MJM and on June 16, 1973, by members of A.A.S. Probably nest in the area.
Least flycatcher *Empidonax minimus* (Baird and Baird)	Reported on May 22, 1971, by WAD and HAW, on June 7, 1971, by CAM, on May 30, 1972, by FGH, and on June 1, 1972, by CAM. All observations were in Hotel Gulch.
Hammond's flycatcher *Empidonax hammondii* (Xantus)	One was observed in Spruce Gulch on June 2, 1971, by REP. Observed in headquarters area by MJM and in Hotel Gulch by members of A.A.S. on June 16, 1973. Probably more common than these records indicate.
Cliff swallow *Petrochelidon pyrrhonota* (Vieillot)	Seen near Manitou Lake on May 22, 1971, by FJH, and on June 10, 1971, by CAM.
Blue jay *Cyanocitta cristata* (Linnaeus)	One was seen in the headquarters area on June 6, 1967, and another on Sept. 3, 1968, by MCH. One was observed at Camp Elim on Oct. 20, 1971, by POC and MJM; BK saw one at headquarters on Oct. 17, 1975.
Scrub jay *Aphelocoma coerulescens* (Bosc)	One was observed in the headquarters area on Sept. 15, 1968, by MCH.
Bushit *Psaltriparus minimus* (Townsend)	One was reported at Painted Rocks Campground on May 22, 1971, by GRS.
Canon wren *Catherpes mexicanus* (Swainson)	One was collected near West Creek on July 24, 1969, by REP.
Rock wren *Salpinctes obsoletus* (Say)	One was seen by MJM and CAM on June 3, 1973, at Colorado Campground.
Swainson's thrush *Catharus ustulatus* (Nuttall)	Reported by FGH on June 25, 1972.
Veery *Catharus fuscescens* (Stephens)	Two were observed at Manitou Lake by DAB during the period June 15-30, 1972. Photographs were obtained (Colo. Field Ornithol. No. 16, p. 24. June 1973). One was heard and seen in lower Hotel Gulch on June 16, 1973, by MJM.
Bohemian waxwing *Bombycilla garrulus* (Linnaeus)	Two flocks were seen in Long Gulch on Apr. 30, 1968, by REP.
Solitary vireo *Vireo solitarius* (Wilson)	One was mist netted in Stone Gulch on June 10, 1969; another was seen by REP in the same area on June 18, 1969. Reported by FJH on May 22, 1971. A female was observed on a nest in a small ponderosa pine from June 10-23, 1976, by MJM.
Virginia's warbler *Vermivora virginiae* (Baird)	One was seen near Phantom Creek on Aug. 14, 1969, by REP. Three were observed near Trout Creek on June 16, 1973, by members of A.A.S.

Species	Notes
Magnolia warbler *Dendroica magnolia* (Wilson)	One reported on May 22, 1971, by AC and MSs.
Townsend's warbler *Dendroica townsendi* (Townsend)	Observed near Phantom Creek on Aug. 15, 1969, and in Spruce Gulch on Aug. 20, 1969, by REP. Several flocks were seen in the West Creek area on Aug. 28, 1969, by REP.
Northern waterthrush *Seiurus noveboracensis* (Gmelin)	Two were seen below Manitou Lake dam on Sept. 9, 1971, by MJM.
Yellow-breasted chat *Icteria virens* (Linnaeus)	One was seen near the highway at the north end of the Experimental Forest on July 25, 1972, by FGH.
Bobolink *Dolichonyx oryzivorus* (Linnaeus)	A female reported at Manitou Lake on May 22, 1971, by SWG (Colo. Field Ornithol. No. 9, p. 39. July 1971).
Yellow-headed blackbird *Xanthocephalus xanthocephalus* (Bonaparte)	Observed by MCH for a 10-day period beginning Apr. 24, 1969, and on May 22, 1971, by FJH.
Northern oriole *Icterus galbula* (Linnaeus)	One was seen by MCH at headquarters on May 18-19, 1969. One was seen at headquarters on May 19, 1970, and another on May 20, 1970, by FLH and MCH.
Rusty blackbird *Euphagus carolinus* (Muller)	Eight were reported by MCH on Aug. 8, 1967.
Common grackle *Quiscalus quiscula* (Linnaeus)	Seen in headquarters area by CAM on May 31, 1972. Observed on July 21, 1972, by FGH, and on Apr. 29, 1974, by FGH and CAM.
Scarlet tanager *Piranga olivacea* (Gmelin)	One was observed by SM and MS at Painted Rocks Campground on May 22, 1971.
Rose-breasted grosbeak *Pheucticus ludovicianus* (Linnaeus)	Two were seen in the headquarters area on June 16-17, 1967, by FLH, MCH, and MJM. One was seen at headquarters by FLH and MCH on May 29-30, 1970.
Lazuli bunting *Passerina amoena* (Say)	Two were observed on July 6, 1967, at headquarters by MCH. One was seen near Trout Creek by CAM on Aug. 25, 1971, and by MJM on Sept. 10, 1971.
Evening grosbeak *Hesperiphona vespertina* (Cooper)	A female was observed at headquarters on June 2, 1970, by MCH. REP saw one pair near Manchester Creek on July 8, 1971.
House finch *Carpodacus mexicanus* (Muller)	Formerly fairly common around headquarters area from early June until late summer during the years, 1966 through 1970, probably because of feeders maintained by MCH. Only other observation was by FGH on July 21, 1972.
Pine grosbeak *Pinicola enucleator* (Linnaeus)	Two males were seen near White Spruce Gulch on Dec. 12, 1967, by MCH.
Gray-crowned rosy finch *Leucosticte tephrocotis* (Swainson)	Seven were seen at headquarters on Feb. 14, 1973, by CAM.
American goldfinch *Spinus tristis* (Linnaeus)	Observed on May 22, 1971, by FJH.
Lesser goldfinch *Spinus psaltria* (Say)	One was seen on June 16, 1973, by members of A.A.S.
White-winged crossbill *Loxia leucoptera* Gmelin	Four males were observed at headquarters on Apr. 2, 1970, by MCH.
Rufous-sided towhee *Pipilo erythrophthalmus* (Linnaeus)	One was seen near Trout Creek on May 22, 1974, by RGB and MJM.
Tree sparrow *Spizella arborea* (Wilson)	One was reported on Apr. 17, 1974, by CAM.

Species	Notes
Clay-colored sparrow *Spizella pallida* (Swainson)	Observed near Trail Creek on May 11, 1969, by REP. Several were seen near Trout Creek on Aug. 28, 1972, by MJM and CAM.
Brewer's sparrow *Spizella breweri* Cassin	Seen in Long Gulch on Apr. 30, 1968, by REP. Observed on Sept. 10, 1971, by MJM and on May 13, 1974, by CAM near Trout Creek.
White-crowned sparrow *Zonotrichia leucophrys* (Forster)	Seen in Long Gulch on May 26, 1969, and on June 13, 1970, by REP. Observed at Manitou on Sept. 29, 1971, by MJM; near Phantom Creek, on May 23, 1972, by REP; and at Manitou on Apr. 30, 1974, by FGH and CAM.
Fox sparrow *Passerella iliaca* (Merrem)	Two were seen below the dam at Manitou Lake on Sept. 7, 1971, by MJM.

Mammals

Mammal investigations at Manitou Experimental Forest have been directed mostly toward the smaller herbivorous mammals, primarily because of their potential impact on forest, range, and recreational resources. From 1957 through 1963, small mammal populations were sampled on ponderosa pine-bunchgrass ranges where light, moderate, heavy, and no-cattle grazing treatments were in effect. In 1974, populations on a campground site and on a nearby grazed area in the ponderosa pine-bunchgrass type were studied. Live- and snap-trap methods were used in sampling.

Records of mammals resulting from trapping and from field observations on the Experimental





Forest (table 2) were found to closely agree w distributional records for mammals in Teller a Douglas Counties (Armstrong 1972). For m species, nomenclature follows Blair and oth (1957). A few species, particularly gold mantled and thirteen-lined ground squirr and prairie dogs, follow Armstrong (1972).

Relative abundance is expressed in five ca gories. Comments on abundance of each spec apply to areas of suitable habitat. Also in cc ments about mammalian habitats, the op grassland type discussed in the section on vege tion is referred to as a grass-forb type, and higher elevation forest east of Highway 67 called mixed conifer. This is a composite of the niferous types discussed previously.

Table 2.—Mammals recorded at Manitou Experimental Forest, Colorado, as a result of trapping or of field observations, with relative abundance in five categories, and whether study skins are on deposit at field station of National Fish and Wildlife Laboratory, Fort Collins, Colorado

Species	Relative abundance[1]					Study skin on deposit	Notes
	Uncertain	Casual visitor	Rare	Common	Abundant		
Shrews and Moles (Insectivora):							
Masked shrew *Sorex cinereus* Kerr			X				Grass-forb habitat. Locally distributed. Caught by traps only in exclosures constructed to exclude grazing and located in open grassland where herbaceous vegetation was most abundant. Fluctuations in population levels between years apparent. Sampling with traps indicated that 1958 and 1962 were high population years.
Vagrant shrew *Sorex vagrans* Baird			X				Habitat and population status similar to that of the masked shrew.
Water shrew *Sorex palustris* Richardson			X				Near aquatic habitats, particularly where herbaceous ground cover is abundant.
Bats (Chiroptera):							
Little brown bat *Myotis lucifugus* (Le Conte)	X					X	One was caught on July 24, 1975, over a water pool in Missouri Gulch.
Silver-haired bat *Lasionycteris noctivagans* (Le Conte)	X					X	Five were caught between July 22 and July 25, 1975, over water in Trout Creek immediately west of headquarters.
Hoary bat *Lasiurus cinereus* (Beauvois)	X					X	Eight were caught between July 22 and 25, 1975, over water in Trout Creek immediately west of headquarters.
Pikas, Rabbits, and Hares (Lagomorpha):							
Mountain cottontail *Sylvilagus nuttalli* (Bachman)				X		X	Edges in uplands and brushy and riparian areas. Populations tend to fluctuate between years.
White-tailed jackrabbit *Lepus townsendi* Bachman			X				Grass-forb and open ponderosa pine habitats.
Squirrels, Mice, and Rats (Rodentia):							
Least chipmunk *Eutamias minimus* (Bachman)				X		X	Primarily ponderosa pine, mixed conifer, and, to a lesser extent, grass-forb habitats. Populations tend to fluctuate annually. Highest population estimate, two per acre, occurred in 1962 in ungrazed, open ponderosa pine.
Colorado chipmunk *Eutamias quadrivittatus* (Say)			X				Rocky outcrops, open ponderosa pine, and mixed coniferous forest. Populations tend to fluctuate annually.
Yellow-bellied marmot *Marmota flaviventris* (Audubon and Bachman)			X				Rocky areas, particularly where succulent green forage is available.
Thirteen-lined ground squirrel *Spermophilus tridecemlineatus* (Mitchill)			X			X	Grass forb and open ponderosa pine habitats. Population locally distributed. Found in pastures west of Highway 67. Population largest on ungrazed grass-forb range. There were about three per acre on ungrazed range in 1959 and 1961. On grazed range, there was less than one per acre in all 7 years of sampling.
Golden-mantled ground squirrel *Spermophilus lateralis* Cuvier				X		X	Rocky areas, ponderosa pine, mixed conifer, and adjacent grass-forb openings.
Gunnison's prairie dog *Cynomys gunnisoni* (Baird)				X		X	Grass-forb habitat. Population locally distributed. Currently, one large town occurs immediately east of Manitou Lake.

Species	Relative abundance[1]					Study skin on deposit	Notes
	Uncertain	Casual visitor	Rare	Common	Abundant		
Abert's squirrel *Sciurus aberti* Woodhouse				X		X	Ponderosa pine habitat. Size of popula tion tends to vary in time, dependen upon quality and quantity of foo sources (seeds and inner bark of pon derosa pine) and by condition of th pine stand (Keith 1965, Patton 1975).
Red squirrel *Tamiasciurus hudsonicus* (Erxleben)				X		X	Found in mixed conifer and ponderos pine habitats.
Northern pocket gopher *Thomomys talpoides* (Richardson)				X		X	Grass-forb and open pine habitats. Pop ulations smaller on grazed (1 to 6 pe acre) than on ungrazed ranges (4 to 1 per acre).
Beaver *Castor canadensis* Kuhl				X			Aquatic habitat. Currently found alon Trout Creek and Hotel Gulch wate courses.
Deer mouse *Peromyscus maniculatus* (Wagner)				X		X	Cosmopolitan. Generally distribute throughout the Experimental Fores Sampling suggests that population are largest in ungrazed, open ponderos pine habitat. Late summer populatior varied from half to three per acre, 195 63. Populations tend to fluctuate fro year to year.
Mexican woodrat *Neotoma mexicana* (Baird)			X			X	Open woodland, shrub, and rocky area (Finley 1958).
Bushy-tailed woodrat *Neotoma cinerea* (Ord)			X				Cosmopolitan. Rocky areas (Finle 1958).
Red-backed vole *Clethrionomys gapperi* (Vigors)				X			Mixed conifer habitat.
Meadow vole *Microtus pennsylvanicus* (Ord)				X		X	Grass-forb habitat. Prefer undisturbe herbaceous stands. Populations va from year to year. Most abundant open grass-forb exclosures (0 to 31 p acre). Population highs occurred 1958 and 1962 (31 and 12 per acre, r spectively). Mostly absent from graz ranges, even in years of high popu tions.
Long-tailed vole *Microtus longicaudus* (Merriam)				X		X	Mesic meadows, brushy streamsides, a upland hillsides.
Muskrat *Ondatra zibethicus* (Linnaeus)				X			Aquatic habitats. Presently found alo Trout Creek and in Manitou Lake.
Western jumping mouse *Zapus princeps* Allen			X			X	Grass-forb and mesic meadow habita Populations vary from year to year.
Porcupine *Erethizon dorsatum* (Linnaeus)				X			Ponderosa pine and mixed conifer ha tats.
Flesh-Eaters (Carnivora):							
Coyote *Canis latrans* Say					X		Cosmopolitan. Sight and sound reco especially common in last 10 years.
Red fox *Vulpes vulpes* Linnaeus		X					Cosmopolitan.
Gray fox *Urocyon cinereoargenteus* (Schreber)		X					Cosmopolitan
Raccoon *Procyon lotor* (Linnaeus)				X			Near aquatic habitats.
Black bear *Ursus americanus* Pallas				X			Cosmopolitan. Population increas in last 10 years.

Species	Relative abundance[1]					Study skin on deposit	Notes
	Uncertain	Casual visitor	Rare	Common	Abundant		
Long-tailed weasel *Mustela frenata* Lichtenstein				X			Cosmopolitan. One was caught on Aug. 2, 1963, in a live trap set in an exclosure in grass-forb habitat.
Mink *Mustela vison* Schreber			X				Near aquatic habitats.
Badger *Taxidea taxus* (Schreber)			X				Grass-forb and ponderosa pine habitats.
Striped skunk *Mephitis mephitis* (Schreber)				X			Cosmopolitan.
Mountain lion *Felis concolor* Linnaeus		X					Cosmopolitan. Tracks were sighted as recently as winter, 1975-76.
Bobcat *Lynx rufus* (Schreber)				X			Cosmopolitan.
Even-Toed Ungulates (Artiodactyla):							
Elk *Cervus canadensis* Erxleben		X					Cosmopolitan. A few animals frequent the Experimental Forest in winter.
Mule deer *Odocoileus hemionus* (Rafinesque)				X			Cosmopolitan.
Pronghorn *Antilocapra americana* (Ord)		X					Open grass-forb habitat.

Relative abundance is expressed in five categories. Comments on abundance of each species apply to areas of suitable habitat.

Uncertain—Known to be present, but relative abundance not known.

Casual visitor—May venture on Experimental Forest occasionally.

Rare—Seldom observed.

Common—Regularly observed by sight, sound, or sign, or caught by traps in suitable habitat.

Abundant—Frequently observed by sight, sound, or sign, or caught in traps in suitable habitat.



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Common and Scientific Names of Plants Mentioned

Grasses and Grasslike Plants

Arizona fescue	*Festuca arizonica* Vasey
Baltic rush	*Juncus balticus* Willd.
Big bluegrass	*Poa ampla* Merr.
Blue grama	*Bouteloua gracilis* (H.B.K.) Steud.
Brome	*Bromus* spp.
Kentucky bluegrass	*Poa pratensis* L.
Little bluestem	*Andropogon scoparius* Michx.
Mountain muhly	*Muhlenbergia montana* (Nutt.) Hitchc.
Northern reedgrass	*Calamagrostis inexpansa* Gray
Rush	*Juncus* spp.
Russian wildrye	*Elymus junceus* Fisch.
Sedge	*Carex* spp.
Sleepygrass	*Stipa robusta* (Vasey) Scribn.
Smooth brome	*Bromus inermis* Leyss.
Wheatgrass	*Agropyron* spp.

Forbs

Aster	*Aster* spp.
Butter-and-eggs toadflax	*Linaria vulgaris* Mill.
European strawberry	*Fragaria vesca* L.
Fleabane	*Erigeron* spp.
Fremont geranium	*Geranium fremontii* Torr.
Geranium	*Geranium* spp.
Hairy goldaster	*Chrysopsis villosa* (Pursh) DC.
Northern bedstraw	*Galium boreale* L.
Pussytoes	*Antennaria* spp.
Smooth horsetail	*Equisetum laevigatum* A. Br.
Stemless hymenoxys	*Hymenoxys acaulis* (Pursh) Parker
Yellowdot saxifrage	*Saxifraga bronchialis* L.

Trees and Shrubs

Bearberry	*Arctostaphylos uva-ursi* (L.) Spreng.
Blue spruce	*Picea pungens* Engelm.
Cliff jamesia	*Jamesia americana* T. + G.
Common chokecherry	*Prunus virginiana* L.
Common juniper	*Juniperus communis* L.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Engelmann spruce	*Picea engelmannii* Parry
Fringed sagebrush	*Artemisia frigida* (Willd.)
Lodgepole pine	*Pinus contorta* Dougl.
Mountain ninebark	*Physocarpus monogynus* (Torr.) Coult.
Ponderosa pine	*Pinus ponderosa* Laws.
Quaking aspen	*Populus tremuloides* Michx.
RockyMountain clematis	*Clematis pseudoalpina* (Kuntze) A. Nels.
RockyMountain maple	*Acer glabrum* Torr.
RockyMountain whortleberry	*Vaccinium myrtillus* L.
Rose	*Rosa* spp.
Shubby cinquefoil	*Potentilla fruticosa* L.
Skunkbush sumac	*Rhus trilobata* Nutt.
Southwestern dwarf mistletoe	*Arceuthobium vaginatum* (Willd.) Presl.
Thinleaf alder	*Alnus tenuifolia* Nutt.
True mountain-mahogany	*Cercocarpus montanus* Raf.
Water birch	*Betula occidentalis* Hook.
Wax currant	*Ribes cereum* Dougl.
Willow	*Salix* spp.

Agriculture—CSU, Fort Collins


DIXON

Morris, Meredith J., Vincent H. Reid, Richard E. Pillmore, and Mary C. Hammer. 1977. Birds and mammals of Manitou Experimental Forest, Colorado. USDA For. Serv. Gen. Tech. Rep. RM-38, 17 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Seasonal occurrence, relative abundance, and habitat preference are listed for 90 bird and 41 mammal species that can be found at Manitou Experimental Forest. An annotated list is given also for an additional 70 casual or accidental bird species. Manitou Experimental Forest is located near Colorado Springs in the montane zone of the Colorado Front Range.

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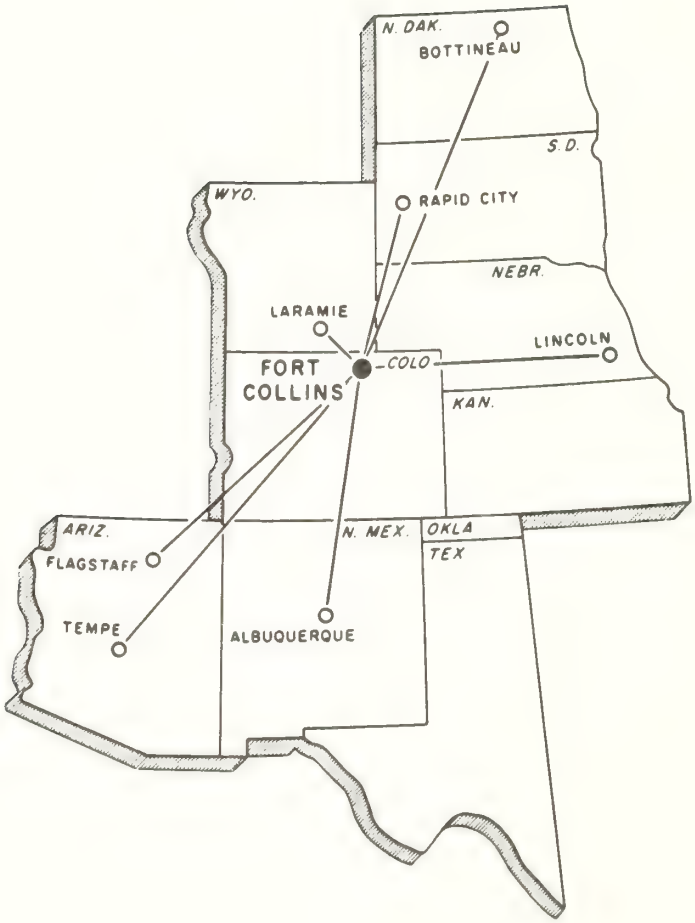
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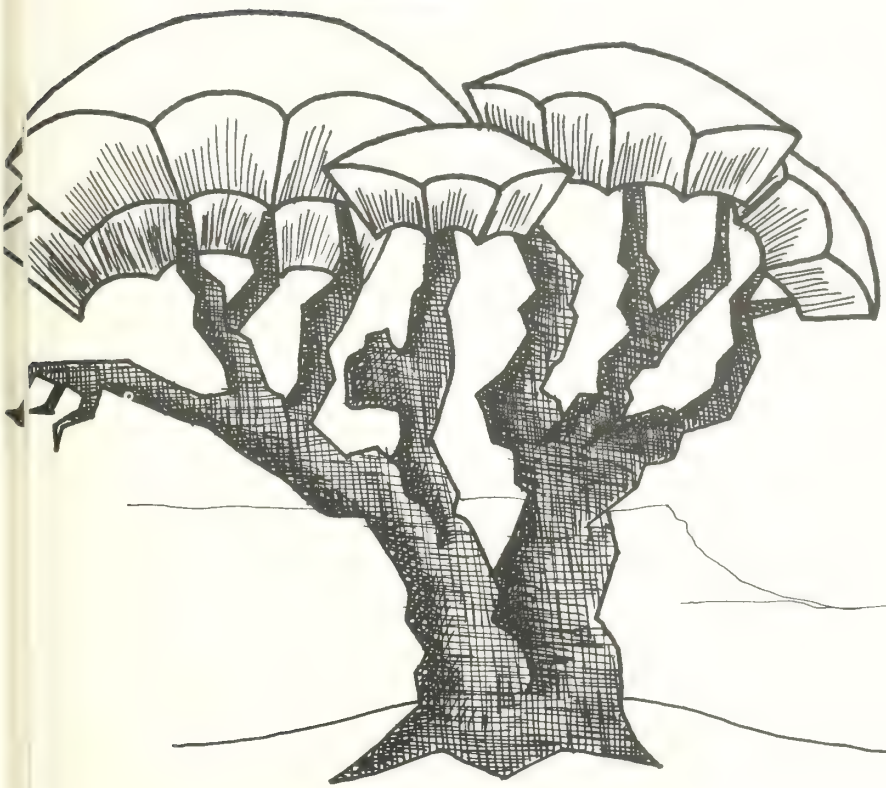
Ecology, Uses, and Management of Pinyon-Juniper Woodlands

Proceedings of the Workshop

March 24-25, 1977
Albuquerque, New Mexico



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Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture
Fort Collins, Colorado 80521

USDA Forest Service
General Technical Report RM-39

Abstract

Aldon, Earl F., and Thomas J. Loring, tech. coord. 1977. Ecology, uses, and management of pinyon-juniper woodlands: Proceedings of the workshop. [Albuquerque, N. M., Mar. 24-25, 1977.] USDA For. Serv. Gen. Tech. Rep. RM-39, 48 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

It is estimated the pinyon-juniper woodland type occupies 33 million acres in the western United States. This vast resource has great potential for social benefits. Our knowledge of the type is summarized in 12 papers in three areas: Ecology of the type, uses and potentials, and management strategies for the woodland zone.

Keywords: Pinyon-juniper, forest utilization

Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.



USDA Forest Service
General Technical Report RM-39

Ecology, Uses, and Management of Pinyon-Juniper Woodlands

Proceedings of the Workshop

March 24-25, 1977
Albuquerque, New Mexico

Earl F. Aldon and Thomas J. Loring
Technical Coordinators

Sponsored by:

Society of American Foresters—Southwestern Section

New Mexico Department of State Forestry

Region 3 and Rocky Mountain Forest and Range Experiment Station,
Forest Service, U.S. Department of Agriculture

Foreword

With the recognition that pinyon-juniper woodlands occupy 33 million acres in the Southwest, it became obvious to the sponsors of the workshop that knowledge and understanding of management needs and opportunities were lacking to properly handle this vast resource.

As a first step toward filling this need, the Southwest Section of the Society of American Foresters, Region 3 of the U. S. Forest Service, the Rocky Mountain Forest and Range Experiment Station, and the New Mexico Dept. of State Forestry brought together these participants to discuss in depth the ecology and management possibilities of the Southwest pinyon-juniper woodlands.

These papers, ranging from general topics dealing with multiple benefits to very specifi papers dealing with procedures for inventories illustrate the wide range of subject matter presented at this workshop. An obvious omission was the water and sediment yields generated from the type. However, this topic is broad enough to merit a workshop of its own

The Coordinators commend the participants and thank the sponsors for what may well becom a landmark workshop in the management and utilization of the Southwest woodland type. We thank the authors for their efforts; articl are published verbatim in this report in the interest of timeliness.

Earl F. Aldon
Thomas J. Loring
Technical Coordinators

The Workshop
March 24-25, 1977

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The Southwestern Pinyon-Juniper Ecosystem

Rex D. Pieper [1/]

The pinyon-juniper vegetational type represents a resource which has been neglected in the past, but which has received a considerable amount of attention recently. Evidence of the increased interest in the pinyon-juniper type is the review by Springfield (1976), the Symposium at Utah State University (Gifford and Busby 1975) and the bibliography by Aldon and Springfield (1973).

The main purpose of this paper is to set the stage for other papers in the program. The presentation will be largely descriptive and will not include information on ecosystem functioning.

DISTRIBUTION AND AREA

The pinyon-juniper type is widely distributed in the Southwest as shown in maps presented by Aldon and Springfield (1973) and Clary (1975). Table 1 shows that New Mexico has the largest area of pinyon-juniper vegetation among the four southwestern states of Arizona, Colorado, Nevada, and New Mexico. Colorado has the smallest area with only 9.0 percent of the state covered by pinyon-juniper vegetation. In New Mexico some of the trees are scattered, and there's always a problem drawing lines around types.

Elevationally, pinyon-juniper stands occur in the foothills above desert or grassland vegetation but below ponderosa pine forests. In the Southwest elevations range from about 5000 ft. to over 7500 ft.

Table 1.--Area occupied by pinyon-juniper vegetation in the southwest (from West. et al. 1975).

State	Square Miles	Percent of State
Arizona	19,695	17.3
Colorado	9,367	9.0
Nevada	20,520	18.6
New Mexico	32,199	26.5

1/ Professor of Range Science, New Mexico State University, Las Cruces, New Mexico.

CLIMATE

Climatic patterns vary considerably within the pinyon-juniper type (Table 2). In some areas such as those in Northern Arizona and Southern Utah, precipitation is mainly winter-spring while further south it comes mostly during the summer. Temperatures also vary considerably, and with precipitation distribution, form several distinct patterns shown in Table 2. Precipitation totals are lower in this type than in forest types at higher elevations.

Table 2.--Climatic characteristics of southwestern, pinyon-juniper vegetation types. (From Springfield 1976).

Climate	Precipitation (means) Winter	Summer
Cool, moist	10	8
Warm, moist	11	7
Cool, winter dry	6	8
Warm, winter dry	6	10
Cold, winter dry	5	9
Cold, summer dry	8	5
Warm, summer dry	8	5

SOIL

Soils also vary considerably over the range of the pinyon-juniper type. Three characteristics have been identified with pinyon-juniper soils:

1. Shallow
2. Rocky
3. Low in fertility

Of course, there are many soils under pinyon-juniper stands which do not fit these characteristics. Pinyon-juniper soils have developed from a wide range of parent materials in the Southwest (Springfield 1967):

Sandstones
Limestones (Dolomites)
Shales
Basalt (Gem-Springerville)
Granite.

It's not surprising that soils would be variable with these parent materials and climates throughout the range of pinyon-juniper.

OVERSTORY VEGETATION

In the Southwest the main species of the juniper component are as follows:

Utah juniper - *Juniperus oteosperma*
Rocky mountain juniper - *J. scopulorum*
One-seed juniper - *J. monosperma*
Alligator juniper - *J. deppeana*.

Rocky mountain juniper is the most widely distributed species, occurring throughout the West from British Columbia to New Mexico (Little 1971). Utah juniper is widely distributed in Utah, Northern Arizona, and some of the surrounding states. One-seed juniper is widespread in New Mexico and Arizona where it is often the dominant tree. Alligator juniper is abundant in Western New Mexico and Arizona, although it also occurs in other areas. The maps of Little (1971) are excellent sources of distributional data on these species.

The pinyon component is composed of these species:

Pinyon pine - *Pinus edulis*
Single leaf pinyon - *P. monophylla*
Mexican pinyon - *P. cembroides*.

Mexican pinyon is found largely in southern Arizona and northern Mexico. The center of distribution of pinyon pine is Nevada. Singleleaf pinyon is widely distributed in Utah, Colorado, Arizona and New Mexico (fig. 1). Apparently there are some hybrids between the two species (Lanner 1975). However, even though there is some gene exchange between these two populations, they remain reasonably distinct and Lanner (1975) recommended the recognition of the two species. Table 3 shows overstory composition of several pinyon-juniper stands in the Southwest.

The pines tend to increase in abundance as elevations increase while the junipers decrease (fig. 2).

SHRUBBY COMPONENTS

Shrubby species are often codominant with the trees in many of these stands. Table 4 lists some of the important shrubs in different areas. The northern region refers to northern Arizona and New Mexico; the southwestern region refers to southwestern New Mexico and southern Arizona; and the southeastern region refers to central and southeastern New Mexico. Big sa brush is a common component in the north. I western New Mexico several species of oak ar important and they become more important in northern Chihuahua, Mexico. In central Chihuahua, the junipers and pinyons fade out and the vegetation becomes an oak woodland (Perez, unpublished). In central New Mexico wavyloaf oak (*Quercus undulata*) forms dense stands and often is an understory to pinyon-juniper. Other important species are listed in Table 4.

Herbaceous understory species also vary considerably among pinyon-juniper stands. Table 5 shows some of the most important herbaceous species in different regions. These are some of the most important species but there are many more species which are listed by West (1975).

Many studies have shown that there is an inverse relation between density of trees an herbaceous vegetation (Figure 3). Apparentl reduced light intensity is a major factor in pinyon-juniper stands influencing herbage yields.

Pinyon-juniper vegetation is a major natural resource in the southwestern U.S. A the other papers in this symposium will illustrate, this vegetation type is worthy of stu and intensive management.

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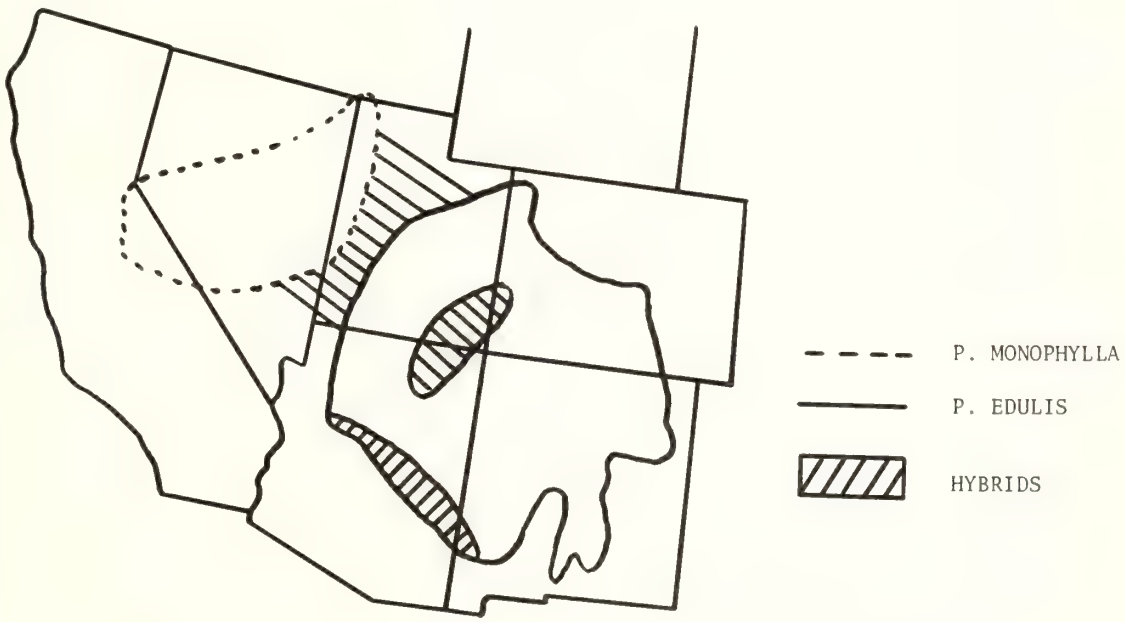


Figure 1. Distribution of pinyon pines (Adapted from Lanner 1975).

Table 3. Composition of overstory vegetation in different areas.

Location	Pinyon pine	Mexican pinyon	Utah Juniper	One-Seed juniper	Alligator juniper
Southern Utah[1]	35		10		
Northern Arizona[2]	30		29		
Southern Arizona[3]		5			67
South-central N.M.[4]	28			9	63
S.E. New Mexico[5]				19	50

[1]From Mason et al. 1967.

[2]From Jameson et al. 1962.

[3]From Whittaker and Niering 1965.

[4]From Lymbery and Pieper, unpublished data.

[5]From Gehlbach 1967.

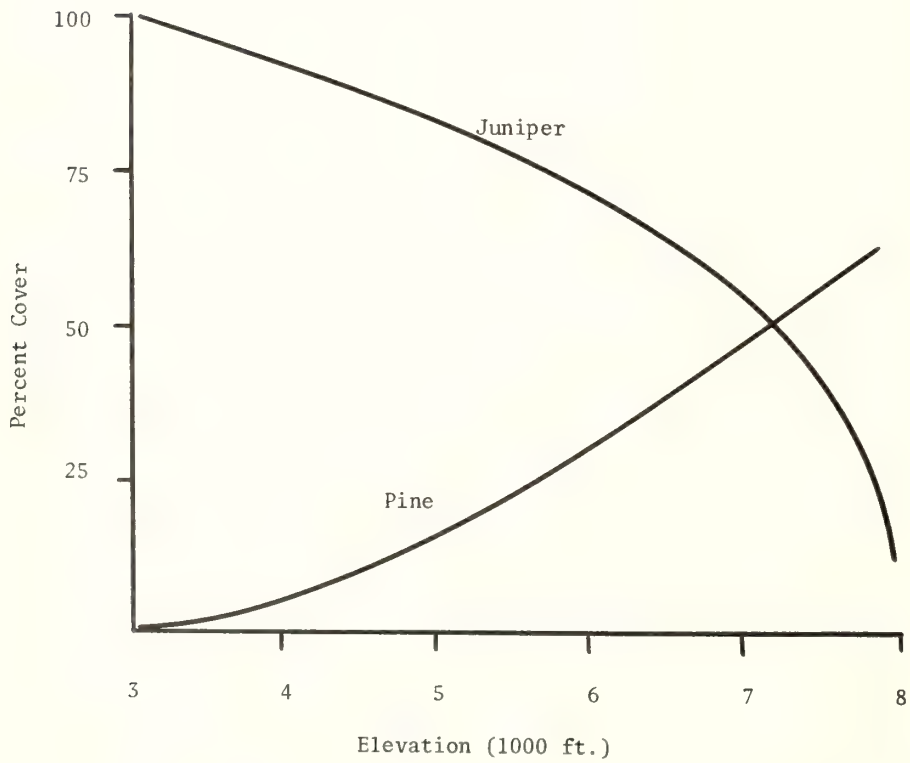


Figure 2. Change of pinyon-juniper cover with elevation. (From Woodin and Lindsey 1954).

Table 4. Important shrubby species in various pinyon-juniper stands in the Southwest.

Northern Region[1]	Southwest Region[2]	Southeast Region[3]
Artemisia tridentata	Quercus arizonica	Quercus undulata
Purshia tridentata	Quercus emoryi	Opuntia imbricata
Xanthocephalum sarothrae	Quercus grisea	Rhus trilobata
Quercus gambelii	Quercus oblongifolia	Dasylirion leiophyllum
Opuntia spp.	Nolina microcarpa	

[1]From Jameson et al. 1962; Thatcher & Hart 1974.

[2]From Whittaker and Niering 1965.

[3]From Gehlbach 1967; Lymbery and Pieper, unpublished data.

Table 5. Important herbaceous species in the understory of pinyon-juniper from different areas.

Northern Region	Southwestern Region	Southeastern Region
Poa longiligula	Muhlenbergia emersleyi	Bouteloua gracilis
Oryzopsis hymenoides	Piptochaetium fimbriatum	Muhlenbergia pauciflora
Stipa speliosa	Eragrostis erosa	Stipa neomexicana
Bouteloua gracilis		Lycurus phleoides
Hilaria jamesii		Aristida spp.

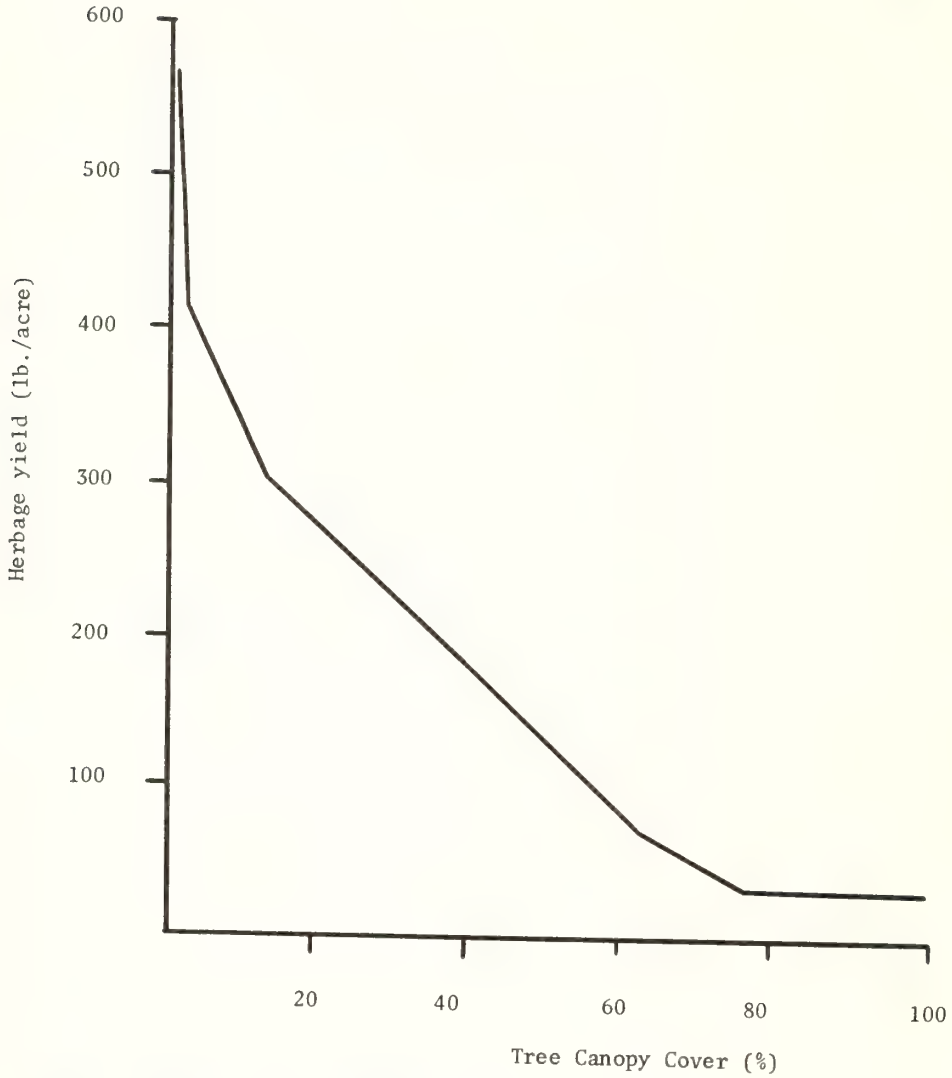


Figure 3. Relation of herbage production to pinyon-juniper canopy cover. (From Arnold, Jameson and Reid 1964).

Pinyon and Juniper Inventory Procedures

Gary W. Clendenen 1/

I appreciate the opportunity to participate in this discussion of pinyon-juniper management. The P-J type occupies a significant area: about 32 percent of the forest land in the Rocky Mountains. Our Renewable Resources Evaluation Work Unit, which has timber inventory and assessment responsibilities in the Rocky Mountain States has been concerned about this type for years. But because its forest product values have been low until recently, we called it noncommercial forest land.

Our interest in the type goes beyond its timber values. We are asking questions about the land and how it is used. Fifteen years ago, my project, in cooperation with range management specialists in the Station and Intermountain Region, proposed to develop inventory techniques for pinyon-juniper land. That proposal included measurements for wood volume and descriptions of understory vegetation and land attributes. Unfortunately, the proposal died from lack of funding. About the same time, some photo volume estimating techniques were developed, but from a very limited data source. To date, our estimates of the P-J resource have been based on these aerial photo techniques. Our estimates of P-J type area are pretty good, but we have little to no information about volumes and land attributes.

Today, we find ourselves in a somewhat different ball game. Interest in the P-J resource is increasing rapidly. I have seen reports of increasing demands for P-J products. Interest in the land for grazing, wildlife habitat, recreation, and watershed values has increased markedly over the last decade.

The first opportunity for our project to become involved in detail in the P-J type came with a request from the Carson National Forest here in New Mexico for assistance in conducting an inventory to develop estimates of the forest product potential of pinyon and juniper land. This request fortunately coincided with an opportunity my project had to acquire some additional money. It also coincided with the Station's opportunity to expand work in the type at our Reno field unit for the study of pinyon-juniper ecology and management. My project is coordinating closely with the Reno effort. The work I'm going to talk about was carried out in cooperation with the Carson National Forest and the Southwestern Region. This work had two primary objectives:

1. As previously mentioned, it was to provide the Forest with information on pinyon-juniper forest product potential;
2. It was to develop a more useful approach to estimating usable wood volume in pinyon-juniper trees.

Every Forester worth his salt knows that diameter at breast height and tree height are required to estimate the volume of wood in trees. It is rather obvious however, when you look at a pinyon or juniper tree that this approach may not be too useful. Almost immediately, the question arises: "Which D.B.H. do we measure?" However, almost every study I have seen on volumes for pinyon and juniper trees has taken this D.B.H.-height approach. With the Carson, we took a different approach altogether. We took the liberty of discarding D.B.H., and adding such measurements as basal diameter and number of stems (Fig. 1 and Fig. 2). I am presently completing the analysis of the data and testing the equations. I can't give a specific volume estimating equation today, but I will give you some of my preliminary findings:

1. Basal diameter is a better volume predictor than D.B.H.
2. Total height is a volume predictor.
3. Number of stems is a volume predictor.

The Reno project is trying to develop estimates of P-J biomass and they are using a similar approach to ours on the Carson. I will be using some of their data to test my results.

When I have completed the analysis, the results will be published. Two publications are planned, and they should be available by the end of the year. These publications will be:

1. Volume Equations and Tables.
2. Inventory Field Procedures for the P-J Type.

1/ Forester, Intermountain Forest and Range Experiment Station, Ogden, Utah

Research in the Pinyon-Juniper Woodland

Elbert L. Little, Jr. [1]

The aims of this article are to review some early research work in the pinyon-juniper woodland in the Southwest and to make suggestions for future research. This vast vegetation type occupies many million acres across several States. It should be managed under multiple use and sustained yield to be more productive and to become a greater source of employment and income for local residents. The high acreage compensates for low unit productivity.

A research project on the pinyon-juniper woodland was begun in 1937 by the former Southwestern Forest and Range Experiment Station, of the Forest Service, United States Department of Agriculture, with headquarters at Tucson, Arizona. I was assigned to that project from September 1937 to December 1941 as assistant forest ecologist (later as associate) to work on pinyon. George S. Meagher, junior forester, began research on juniper early in 1938. However, work was interrupted at the start of World War II, and afterwards the project was discontinued.

Pines and junipers are among the most successful plants in the North Temperature Zone. Both groups of conifers are well adapted to barren sites and as pioneer plants invade dry rocky slopes. In numbers of species, size, area, geographical distribution, habitats, and ecological niches they rank high. These two genera have spread through North America from near the northern limit of trees in Canada across continental United States from coast to coast and southward mainly in mountains to Mexico, tropical Central America, and the West Indies.

The junipers, genus *Juniperus*, have 14 species in the United States, about 15 more in Mexico, Guatemala, and the West Indies, and a world total of about 60. They are native in all 49 States of continental United States and are scattered across the prairie-plains grassland interior, as shown on Map 1, natural distribution in the New World.

The pines, genus *Pinus*, have 36 species in the United States, about 60 in the New World, and a world total of almost 100. Some grow wil in 48 States, all except Kansas and Hawaii, as charted on Map 2, natural distribution in the N World.

THE PINYON-JUNIPER WOODLAND

In the semiarid regions of southwestern United States northwest to the Great Basin and southward into the mountains of Mexico, the pi and junipers have entered and succeeded to for the pinyon-juniper woodland, a widespread vege tation zone of dwarf trees between the forests of the Rocky Mountains and the treeless lowlan grasslands and deserts. This natural woodland type extends from southwestern Texas across Ne Mexico and Arizona to California and north int Nevada, Utah, and Colorado. Junipers continue northward through the five northwestern States where they are conspicuous in the vegetation between the forested mountains and grassland plains. The area of this woodland from Texas to California has been estimated at more than 60,000,000 acres. The term juniper-pinyon woodland perhaps would be more appropriate tha pinyon-juniper, because of the abundance of junipers and their broader geographic distribu tion. The aspect is similar, though the speci composition changes somewhat from one State to another.

In the Southwest a remarkable group of pin has evolved. Pines adapted to this semiarid region by producing a distinct group, the pinyons or nut pines, *Pinus* subsect. Cembroides, with 8 species. Total natural distribution, within the United States and Mexico, is indica in Map 3. Pinyons have limited leaf surfaces short needles, the number in a cluster reduced from 5 in the white or soft pines commonly to or 1. The cones produce relatively few, large wingless, edible seeds well adapted to dispers and burial by rodents and other mammals.

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The common pinyon in the Southwest, sometimes distinguished as two-leaf pinyon, is *Pinus edulis* Engelm., Map 4. Singleleaf pinyon, *Pinus monophylla* Torr. & Frem., in the Great Basin extends south into northwestern Arizona. Mexican pinyon, *Pinus cembroides* Zucc., with needles mostly in 3's, ranges along the Mexican border from central and southwestern Texas to southeastern Arizona. Parry pinyon, *Pinus quadrifolia* Parl., the fourth species in the United States, with needles mostly in 4's, is rare in mountains of southern California but more common southward in northern Baja California, Mexico.

Descriptions of the 3 southwestern species of pinyons and of the 4 junipers and small maps of vegetation types may be found in "Southwestern Trees" (Little 1952). Species distribution maps are in the "Atlas" (Little 1971).

PINYON NUT HARVESTS

The most import product of the pinyon tree (not "pinyon pine") was its large edible nut (technically a seed). The Spanish name piñón (plural piñónes), referring to the large seed of *pino*, pine, has been anglicized to pinyon. A review of this wild nut crop may be appropriate here.

The large edible pinyon nuts have been a staple food of Southwestern Indians ever since arrival many thousand years ago. They were mentioned in reports of all the early Spanish explorers, back to Cabeza de Vaca, Fray Marcos, and Coronado, more than four hundred years ago.

Commercial harvest of pinyon nuts began early in the Twentieth Century. These nuts are similar to the large edible seeds or pignolias from Italian stone pine (*Pinus pinea*) imported from the Mediterranean region. A visitor from the East noticed the resemblance and began shipments to New York City. Pinyon nuts under the name Indian nuts were sold in pushcarts along city streets, especially to persons from southern Europe. The market expanded there, and smaller quantities were sent to other cities such as Chicago and Los Angeles.

The species involved in commercial shipments from New Mexico and northern Arizona was *Pinus edulis*. Its oily nut was preferred in flavor over the larger and thinner shelled, mealy nut of singleleaf pinyon, *Pinus monophylla*, of Nevada and western Utah. Number of fresh, unshelled nuts of the former is about 1,400 to 2,000 to a pound. Within a few months after harvest, there is a shrinkage of as much as 20 percent from loss of moisture.

Annual harvest in the Southwest in the 1930's was about 1,000,000 to 2,000,000 pounds. The largest recorded was 8,000,000 pounds in 1936. Raw unshelled nuts kept well in storage in the dry Southwest, sometimes a year or more until the surplus from large or bumper crops could be sold. They were packed in burlap bags of 100 pounds, or 40,000 pounds to a railroad carload. Thus 1,000,000 pounds occupied 25 carloads.

Pinyon was the largest entirely wild nut crop in the United States. However, its harvest was only a small fraction of that of cultivated nuts, such as pecan, walnut, almond, and filbert. Annual harvest of peanuts, an agricultural crop with similar edible seed, then was about 1,000,000,000 pounds, or nearly 1,000 times as great. (By 1976, current peanut production in the United States has increased to 3,800,000,000 pounds! And the Government buys the surplus!)

Pinyon nut crops, like good seed crops of other pines and various wild trees, are irregular. Large cone crops, the bumper crops, vary in time and place. According to popular superstition, there is a good pinyon nut crop every 7 years. Actually, the time between heavy crops in a locality may be as short as 5 years, rarely only 2 years, or somewhat longer near the range limits.

The commercial region for *Pinus edulis* centers in northern New Mexico, northern Arizona, and southwestern Colorado. Areas with the best and most frequent crops are northwestern New Mexico and northeastern Arizona. Commercial crops are produced occasionally in southern New Mexico.

Most pinyon nuts probably were harvested simply by hand under the trees after cones opened early in October. Where the nuts are abundant, a person can pick as many as 2 pounds an hour or 20 pounds a day. Another method is to rob nests of woodrats, or "packrats". Or the nuts and litter are swept with broom and separated by sieves of hardware cloth. Early in the season, before the nuts fall, a canvas can be put under a tree and the nuts and cones shaken or knocked out. Unopened cones are not picked in the Southwest.

In the 1930's the price paid to pickers was about 10 cents a pound. Local retail price of unshelled raw nuts was about 25 cents a pound. Most nuts were harvested on Government managed lands, mainly National Forests and Indian reservations. Pickers paid no fees.

The pinyon nut crop was gathered mainly by Indians, especially Navajos, and Spanish-Americans. Groups of Navajos would camp in the woodlands each autumn. They sold or bartered

their pinyons at the trading posts on the reservation. Most of the harvest was handled through two large wholesalers in Albuquerque. One bought all the nuts and stored surpluses from one year to the next. Thus it was able to maintain the price and perhaps make a low profit, partly through trading with Indians.

Pinyon nuts marketed locally in the Southwest were mostly unshelled and raw. Those shipped in carload lots to New York City and other cities were unshelled but roasted, polished, and cleaned. A relatively small amount was shelled in Albuquerque and sold roasted or sometimes in candy or confections. One local company developed a special shelling machine.

Thus, the pinyon nut harvest was a source of part-time employment and income for the pickers. This forest product brought some money into the Southwest every year. Also, local residents gathered nuts for home consumption and recreation.

The pinyon nut harvest and market declined rapidly during and after World War II. There was a shortage of labor for harvesting, and the price paid to pickers was forced upward. Also, there was competition with cheaper nuts.

Conversion of natural pinyon-juniper woodlands to grasslands in the Southwest has included destruction of mature pinyon trees on at least a few hundred thousand acres. Certainly the production of pinyon nuts has decreased, because large areas now are treeless.

At present the pinyon nut harvest probably is somewhat lower than before World War II, though figures are not available. Some shipments are made annually from Gallup, Albuquerque, and Flagstaff. One company in Albuquerque handles the local harvest and has a warehouse and shelling machinery.

Current prices (March 1977) in Albuquerque are approximately as follows: Pickers are paid $1.00 to $1.25 a pound. Retail price of raw unshelled nuts is about $1.75 a pound, or roasted unshelled nuts, $2.50 a pound. Also, roasted unshelled nuts are sold in packages, 3 ounces at $.79 and 4 ounces at $.98. Shelled roasted pinyon nuts cost about $5.00 a pound (from 2 pounds of unshelled nuts). These relative increases probably are comparable with those of other nuts through the years based upon higher costs of living and upon inflation.

EARLY RESEARCH ON PINYONS

My early research on pinyons in the Southwest, preliminary and basic, was mainly on the common pinyon, *Pinus edulis* Engelm., and was reported in several publications. These are cited in two detailed bibliographies on pinyon-juniper woodlands by Aldon and Springfield (197 and by West, Cain, and Gifford (1973).

The classification or taxonomy of the pinyo was reviewed. It was obvious that there are fo native species of pinyon, as in Forest Service Check Lists and named above, not a single speci with four varieties differing merely in needle number. Basic differences of commercial as wel as taxonomic importance were noted in the seeds for example, size, thickness of seed coat, chem cal composition, and taste (Little 1950). Afte wards, three minor botanical varieties were named. Detailed analyses of the chemical compo sition of pinyon nuts of different species were made by a cooperative study (Botkin and Shires 1948).

Fort Valley Experimental Forest, "the oldes forest experiment station", served as the headquarters for field work during the four-year period 1937-1941. It is located about 9 miles northwest of Flagstaff, Arizona, within the Coconino National Forest.

An experimental plot designated the Walnut Canyon Pinyon Plot was established in a good natural pinyon-juniper woodland also within th Coconino National Forest about 12 miles east o Flagstaff near Walnut Canyon and Walnut Canyon National Monument. In 1938 a 5-acre plot was fenced in Sec. 30, T. 21 N., R. 9 E. The site at about 6,500 feet altitude was within a few miles of the border of the ponderosa pine forest westward. A climatic station was maintained there and was visited weekly during the field season (Plate 1, lower left and lower right). Stages of growth of the trees, cones, and seeds were recorded (Little 1938a).

A detailed microscopic study of the developing cone, seed, and pollen was made. The stages were normal and like that of other species of pine studied previously. The cone requires two field seasons for maturation including one year between pollination and ferti lization, as in nearly all pines. Also, as in other species, the earliest stages of the cone are formed in the terminal bud the preceding season and are distinguishable by August (Litt 1938b). Thus, three growing seasons are invol in development of cone and seed.

The practical value of this fact, known to specialists, is that a bumper cone crop begins in the third year before maturity and requires three favorable years. Attempts to correlate cone crops with environmental conditions such precipitation and temperature, should be dated accordingly.

A summary of the life history of pinyon

trees, including habitat conditions, was published later (Little 1965). Pinyon seedlings appear usually under the protective cover of low shrubs or in litter under the edge of the crown of parent trees, not in openings or grasslands. Shade and moisture are essential to survival of seedlings, according to an experiment with seed spots at the Walnut Canyon plot by George S. Meagher (1943).

Growth of pinyon trees is extremely slow, about 2 to 6 inches in height annually. Cones are not produced in quantities until trees reach mature size at an age of about 75 to 100 years. Mature trees are about 10 to 30 feet in height and 6 to 18 inches in trunk diameter and 75 to 200 years old up to a maximum of about 400. (The two oldest individuals measured elsewhere in tree-ring investigations were 973 and 853 years.)

At least a few young cones are formed by some trees in a locality each year, though in most years a particular locality has no commercial pinyon nut crop. When only a few cones begin development, mortality from insects and other causes is proportionately high and the cone crop at maturity is a failure. Obviously, a commercial pinyon nut crop is not produced unless the total number of cones beginning development greatly exceeds these losses and also the nuts harvested and stored by rodents before pickers arrive.

A special study of insects on pinyon was made (Little 1943). Insects destroy a very high percentage of cones of a light cone crop and a smaller proportion of a heavy cone crop. The first year, larvae of gall midges kill many cones. The second year, numerous cones and seeds are destroyed by caterpillars of pine cone moths, larvae of small weevils, and pinyon cone beetles.

One problem was how to manage pinyon-juniper woodlands to increase production of the edible seed, pinyon's most valuable product. The solution was simple, merely to pick more nuts. Somewhere in the vast area of pinyon-juniper wood in the Southwest, there is a good pinyon nut crop every year. The procedure was to locate the areas with trees bearing many cones and to pass this information on to pickers. For several years annual estimates or forecasts of the crop with locations were issued in summer (Little 1939, 1940). These were compiled mainly from observations by forest rangers on the National Forests. Similar reports could be resumed, if helpful.

Research was planned to attempt to increase future nut production on natural stands through management (Little 1941). It was suggested that in selection cutting, such as for mine timbers, the best nut producers be left (Little 1940). These mostly are large spreading trees with a broad crown and abundant old cones on the ground beneath.

Preliminary tests of treating trees to increase nut production were begun. These included watering, cultivation, addition of chemical fertilizers, and pruning. However, the work was not continued.

Slight variations in pinyon nuts from tree to tree were observed. Examples were number and size of nuts, also color shades and markings of seed coat. These individual differences could be the basis of some future improvement through selection.

Preliminary tests made to develop methods of controlled pollination and hybridization. Afterwards, the Institute of Forest Genetics of the Forest Service, at Placerville, California, has made interspecific hybrids of pinyons and is growing plants of the progeny.

CONVERSION FROM MULTIPLE USE TO ONE USE, GRAZING

The pinyon-juniper woodland has many uses, even though the unfavorable climate limits plant growth and total annual production per unit area. Obvious products of the wood include fuel, mine timbers, railroad crossties, lumber, novelties, fence posts, and pulpwood. In addition, pinyons provide pinyon nuts, Christmas trees, and ornamentals for transplanting. Other values are forage for livestock, food and habitat for wildlife, and recreation. Water yield from this zone of low precipitation apparently has been very low or negligible.

There were early reports that juniper was invading some areas of grassland in the Southwest. One day our supervisor, G. A. "Gus" Pearson took George S. Meagher to a place near Ashfork to observe the process. I was not invited because pinyons were not involved. Junipers in the Southwest may invade grasslands, just as eastern redcedar (*Juniperus virginiana*) spreads in pastures in the East. This increase apparently is related to grazing, including seed dispersal and trampling, and reduction of plant cover. (Possibly on some areas the junipers, properly managed, might be worth more than the forage.)

During my field work over the Southwest, I saw no evidence that pinyons invaded grasslands. Seedlings were found in the shade of a low shrub, such as rabbitbrush (*Chrysothamnus*) or the edge of the crown of a parent tree, never in the open grassland. Apparently livestock did not aid seed dispersal.

Sometime after World War II, widescale conversion of pinyon-juniper woodlands to grasslands was undertaken in the Southwest and with related species in the Intermountain or Great Basin Region. Treatment on a smaller scale continues at present. The process generally was called control of pinyon-juniper woodland that had invaded grassland.

Over large areas of the Southwest, conversion was accomplished by various methods, such as cabling, bulldozing, hand chopping, sawing, and grubbing, and burning, and even a giant machine called a tree crusher. In Arizona alone, more than a million acres of pinyon-juniper was treated in Arizona in the period 1950-1961, according to range specialists Arnold, Jameson, and Reid (1964, p. 24).

Most of the conversion was outside the National Forests, such as at lower altitudes. There, junipers apparently had invaded grasslands, mostly on the public domain. However, for several years, the acreage converted within the National Forests of New Mexico and Arizona was about 25,000 acres annually. Thus, at least 250,000 acres were treated.

Some information is contained in a 4-page leaflet entitled "Landscape management in pinyon-juniper control" issued by the Southwestern Region (U. S. Dep. Agric., Forest Service, no date). Color photographs included an aerial view of a "control project" of a natural stand, removal of large mature pinyons by a tree crusher, and increased forage production on a good treated site with ponderosa pine trees in the background.

In May 1968, after 30 years, I returned to my Walnut Canyon Pinyon Plot. The fence from untreated juniper posts was still in good condition. Many thousand acres of natural pinyon-juniper woodland for miles around had been converted to grassland and had become a desolate landscape. The area resembled the result of a severe fire, and part had been burned over. From the good pinyon woodland, only the 5 acres within the fenced plot remained, as shown in the six photographs of Plate 1.

This conversion represented a change from multiple use to one use, grazing. The location was near a city, where important values other than forage were lost. Conversion destroyed pinyons, Christmas trees, fuelwood, and fence posts. Also gone were wildlife including deer and other game animals, recreational areas, and scenic values. Here along a national highway and a branch to a National Monument, esthetic aspects should merit consideration. Numerous visitors daily could compare the orchardlike natural woodland with the destroyed woodland, now grassland. A century may lapse before pinyon recovers. However, juniper may come ba rapidly.

Large-scale treatment was not preceded by adequate research or experimental plots. Ther was no previous study of costs and benefits no of the duration and maintenance after conversi At that time environmental impact statements were not required.

CONTROL AND CONVERSION

Two types of areas were treated in the Sou west under the term "control". First, the are of grasslands, mostly at lower altitudes outsi the National Forests, where juniper (but not pinyon) apparently had invaded. Treatment the could be called control or eradication.

Second, the areas of natural pinyon-junipe woodlands, such as the Walnut Canyon Pinyon Pl There is no evidence that this type with matu trees 100-200 years old was formerly a grassl invaded by trees, nor that the trees had increased in density in recent years. Treatmen there was conversion, not control.

Under some conditions one type of natural vegetation can be destroyed and replaced, jus as a forest is cleared and followed by cultiv ted fields. However, without invasion, there no control. The proper term for the artifici change from one vegetation type to another is conversion.

Pinyon (*Pinus edulis*) is a delicate speci of extremely slow growth and long life. I ha seen no evidence that pinyon invades grasslan with juniper. Pinyon seedlings germinate in shade of a tree or shrub, not in the open gra land. Height growth is only about 1 inch annually for the first 10 years or more. Mat pinyon trees 100 to 200 years old antedate he grazing by domestic livestock except possibly near very old Spanish-American settlements, s as limited areas of northern New Mexico. Pin plants can be seen growing in and overtopping low shrubs, such as rabbitbrush (*Chrysothamnu* and sagebrush (*Artemisia tridentata*). Thus, over a long period of time, perhaps a century pinyon might very slowly invade sagebrush or other shrub types. This change in vegetation probably is rare and mostly limited to the sa brush type of northern New Mexico.

The term "conversion" should replace "cor trol" in all discussion and planning involvi treatment of natural pinyon-juniper woodlands such as within the National Forests. There a big difference in the two terms involving vegetation and policies of land management.

Conversion emphasizes that treatment is optional, and that lands may be left alone indefinitely with their natural plant cover. Also, costs and benefits and the effects of manipulation upon the environment should be considered. Further, a converted type may not be stable and may require repeated treatments for maintenance to prevent reversion. Conversion stresses the need for research before action.

SUGGESTIONS FOR FUTURE RESEARCH

This meeting devoted to the pinyon-juniper woodland demonstrates the renewed interest in this widespread vegetation type. Research is in progress at several localities. In conclusion, some suggestions for future research to make this type more productive may be offered here.

A general meeting on pinyon-juniper woodlands in the Southwest, similar to those on other vegetation types such as shrubs and desert plants, should be productive. The object would be to bring together the persons working in this type, both research and management, and should be of mutual benefit. This meeting would be mainly for Federal, State, and University workers but would be open to others, including conservationists, landowners and managers, and the scientific public. The program would include papers by researchers and administrators, field trips, discussions, and planning.

Review of past conversion from woodland to grassland would be desirable. Representative areas converted at different dates and by different methods could be compared. Economic analyses of costs and benefits would be useful. Any changes in composition of vegetation after conversion and the rates could be observed.

More basic research should be helpful in future management. These aspects perhaps merit the most attention: (1) timber management research, including silviculture, timber stand improvement, genetics (production of pinyon nuts, fence posts, etc.), and revegetation with woody plants, including exotics; (2) forest products, including development of new products and uses; and (3) forest economics and marketing, including studies of costs and benefits of different products and treatments.

Genetics offers possibilities for increasing productivity in the distant future. When developed, better pinyon nut bearing trees could gradually replace the wild stands. Junipers might be improved for growing fence posts. Pines better suited for lumber and pulp might be selected and bred. Careful land-use planning should precede future conversion. Multiple use, not just grazing, should be considered. Certain areas could be managed with emphasis on particular values, such as pinyon nuts, fence posts, Christmas trees, game, recreation, etc. On some good sites adjacent to privately owned ranches, conversion to grassland may be the best management.

On other areas, funds equal to cost of conversion to grassland might be better used for other purposes, such as timber stand improvement, revegetation with woody plants, and testing of exotics. Some marginal lands already converted might be restored or revegetated.

In the future, adequate review by specialists in different fields should precede projects involving destruction of natural pinyon-juniper woodland and conversion to grassland.

SUMMARY

From 1937 to 1941 I was assigned to the research project on the pinyon-juniper woodland in the Southwest to work on pinyon, *Pinus edulis*. Area of this woodland from Texas to California has been estimated at more than 60,000,000 acres. The most important product of the pinyon tree was its large edible nut.

The classification or taxonomy of the pinyons was reviewed. An experimental 5-acre fenced plot designated the Walnut Canyon Pinyon Plot was established within the Coconino National Forest about 12 miles east of Flagstaff. There, stages of growth of the trees, cones, and seeds were recorded.

At that time the solution to the problem of increasing production of pinyon nuts was merely to pick more. Annual estimates of the crop with locations were issued in summer. Research was planned to attempt to increase future nut production on natural stands through management.

Sometime after World War II, in the Southwest there was widescale conversion of pinyon-juniper woodlands to grassland from multiple use to one use, grazing. Many thousand acres around my plot were converted to grassland. Two types of treatment were applied under the single term "control". The first, refers to areas of grassland where juniper (but not pinyon) apparently had invaded. Second, the areas of natural pinyon-juniper woodlands, where the treatment was conversion, not control.

Some suggestions for future research to make the pinyon-juniper woodland more productive include a general meeting on pinyon-juniper woodlands in the Southwest and review of past conversion. Also more basic research in (1) tim-

ber management including silviculture, genetics, and revegetation; (2) forest products; and (3) forest economics and marketing. In the future, adequate review should precede conversion.

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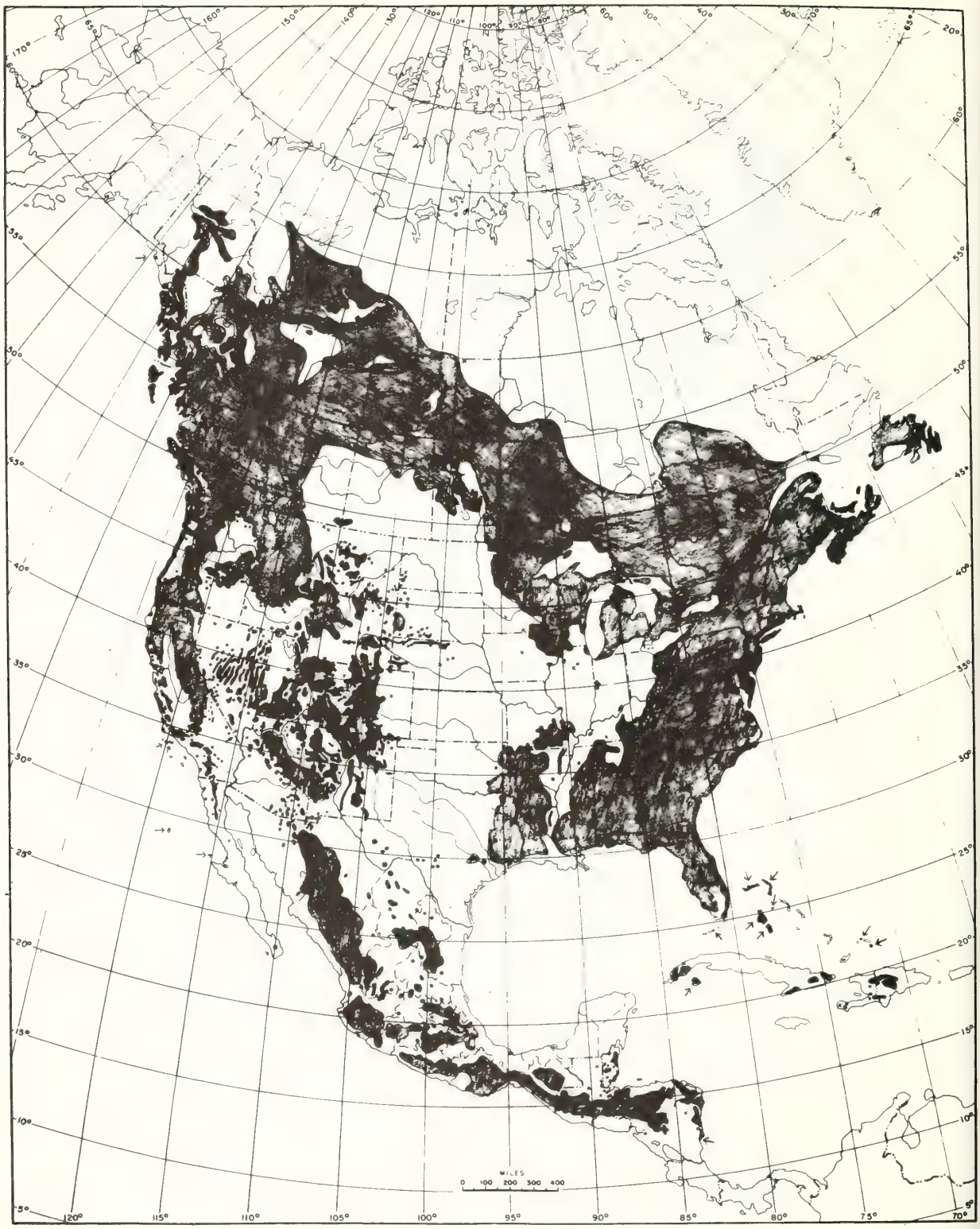
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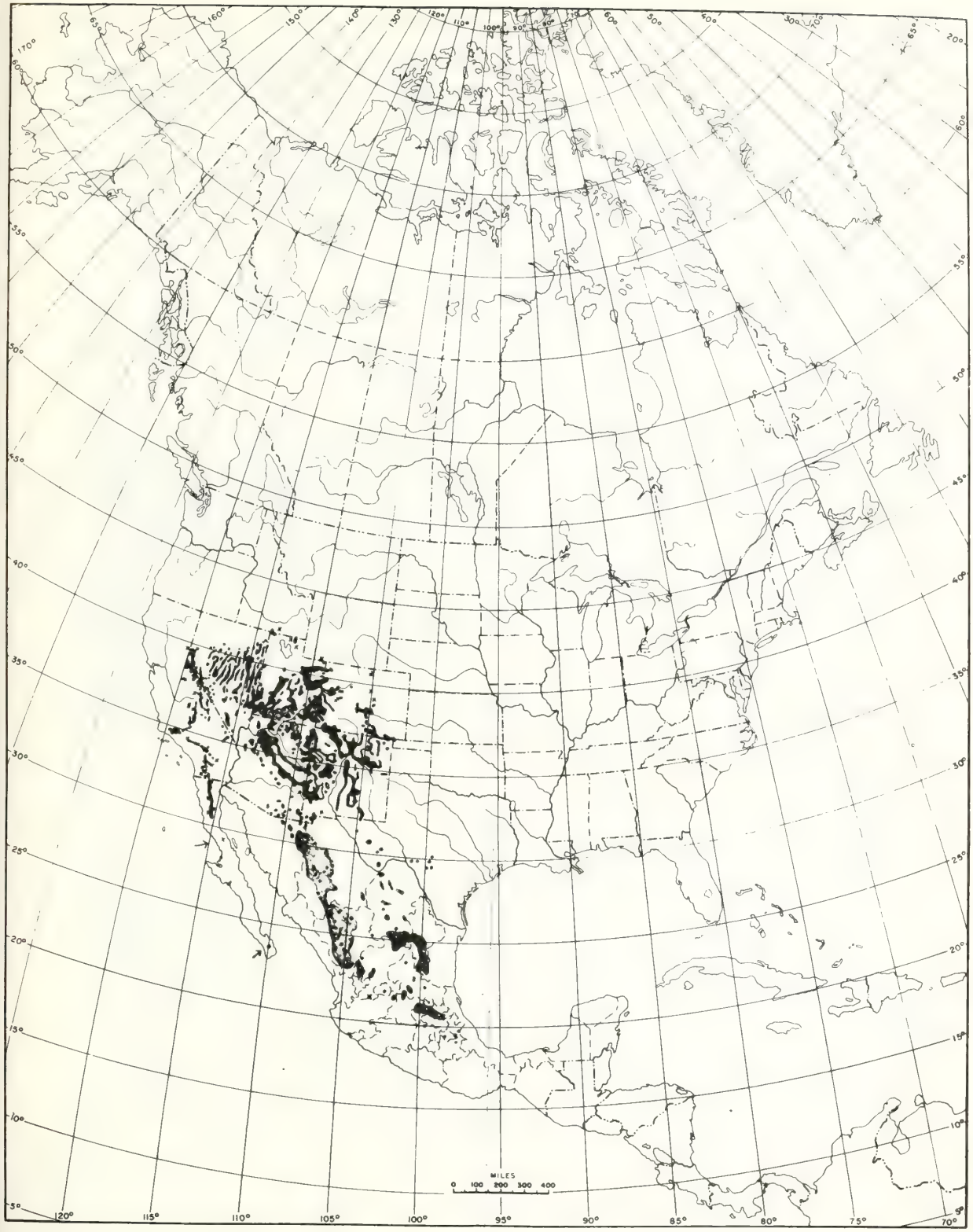


Map 1

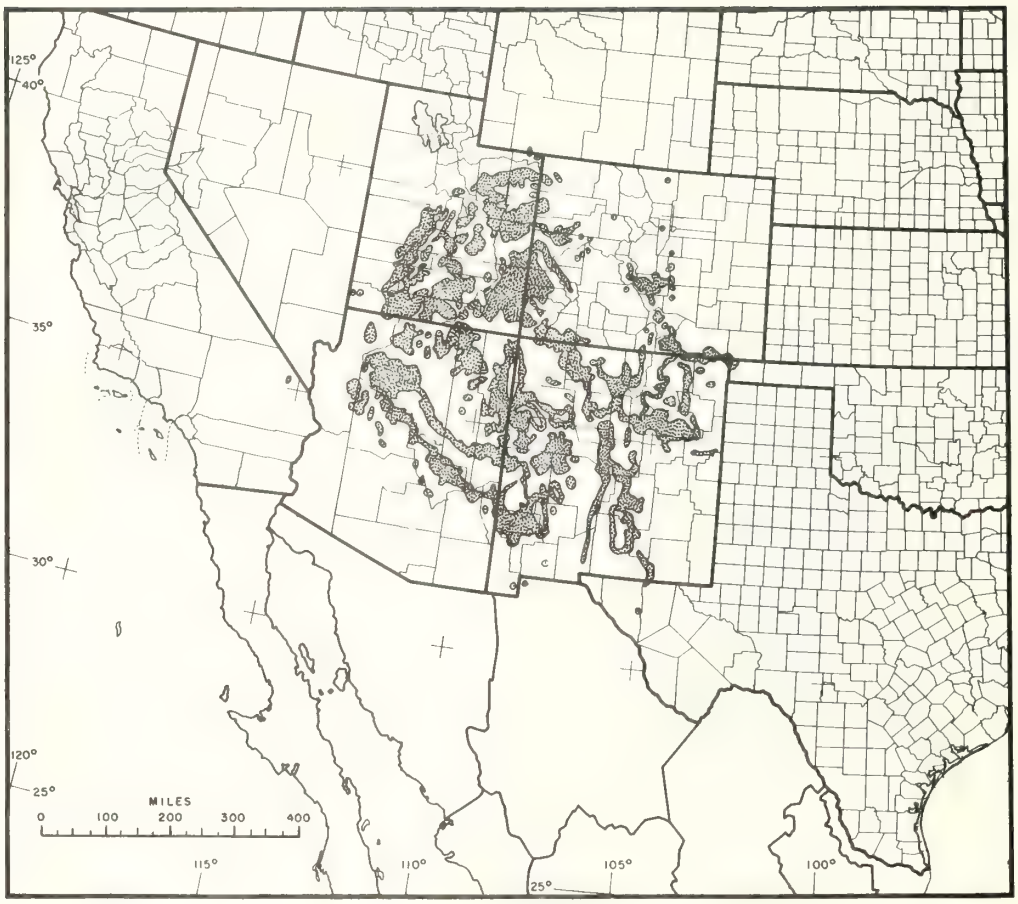
Map 1. Junipers (genus *Juniperus*), natural distribution in the New World.



Map 2. Pines (genus *Pinus*), natural distribution in the New World.



Map 3. Pinyons (*Pinus* subsection *Cembroides*), natural distribution in United States and Mexico.



Map 4

Map 4. Pinyon, *Pinus edulis* Engelm., natural distribution.



ate 1. The Walnut Canyon Pinyon Plot 12 miles east of Flagstaff, Ariz., in May 1968, 30 years after establishment, six photographs. Upper left, upper right, and center left, three views of grassland after conversion, with 5-acre fenced plot of natural pinyon-juniper woodland at left, looking northwest toward San Francisco Peaks in background. Center right, looking northeast along fence, with woodland at right. Lower left and lower right, two views of the climatic station in an opening within the fenced plot, showing natural pinyon-juniper woodland and abandoned instrument shelter.

Insects and Diseases of Pinyon-Juniper

Tony Smith [1]

As the population of the southwest increases, more and more people are coming in contact with Pinyon-Juniper Woodland. Developments, summer homes, and expanding cities are encroaching into the P-J type. As a consequence, more attention is being given to the insects and diseases that attack pinyon and juniper. Some of these insects are important forest pests, some are important in the forest and in the ornamental situation, and some are important only on ornamental trees. Little will be said about diseases except to mention the mistletoes. True mistletoe infects juniper while dwarf mistletoe infects pinyon and they are the most important diseases of P-J. Pruning the infected branches is the only control for mistletoe on ornamentals.

Few insects attack juniper and those that do are not too common and rarely cause extensive damage or mortality. The most common insect that attacks juniper is a cerambycid twig girdler. It causes some twig mortality for a year or two and is a natural pruner of juniper but causes no important permanent damage to the tree.

Many different insects attack pinyon and the most common and important will be discussed here. Pinyon insects will be grouped by mode of feeding and type of damage caused as follows:

INSECTS THAT PRODUCE A CHARACTERISTIC PITCH FLOW AT THE POINT OF ATTACK

Pitch Nodule Moth. Larvae bore into twigs in early spring and produce a hollow ball of pitch about the size of a dime. Eventually the twig is killed and after several years of attack the trees are badly disfigured.

Pine Tip Moth. Orange colored larvae bore into tips and shoots and consume the pith. In June or July the tunneling kills the tip or shoot. Trees from 6 inches to 6 feet are most often attacked and this is an important pest of regeneration and nursery stock. A small 1/2 inch flow of drying pitch at the point where the larva bores into the tip indicates attack. The tips turn brown in summer and fall off the tree.

Ips Engraver Beetles. These beetles have 1 to 5 generations per year and usually cause mortality. Eggs are laid in typical galleries constructed under the bark and the larvae girdl the tree with their feeding in the cambium. Points of attack are marked by boring dust and by small flows of pitch called pitch tubes. Trees weakened by drought or by man's disturbances are attacked first and populations of beetles buildup and can successfully attack healthy trees. Slash is also a source of population buildups.

SUCKING INSECTS - INSECTS THAT REMOVE SAP FROM NEEDLES OR OTHER TREE PARTS

Pinyon Needle Scale. These insects attack and kill last year's foliage and can kill tree in 3 to 4 years time. They are difficult to control legally with insecticides. Unregister systemics give 100 percent control. Region 3 FIDM personnel have developed an alternative t chemical control for ornamentals which consist of washing eggs off the tree with a garden hos and destroying them at the appropriate time. (See - Rky. Mt. For. and Range Exp. Sta. Res. Note RM-270.)

Pine Needle Scale. 1/16 inch white scale insects infesting pinyon needles, especially along dusty roads in areas of air pollution. They attack all pines and other conifers and can cause mortality in 3 to 5 years. Often weaken trees and make them susceptible to att by other insects.

Conifer Aphids. Small, soft-bodied, long legged insects which attack limbs, branches, and tree trunks. They feed by inserting thei mouthparts through the bark. Many generation are produced each year and tree vigor decline rapidly. Mortality can occur in as little as 1 year.

DEFOLIATING INSECTS - INSECTS FEEDING ON NEEDLES

Sawflies. Insects related to bees and wa Larvae are gregarious, non-hairy, and feed on branch until it is bare and then move on to another. They are sometimes pests in regener ation and in plantations, but are easily controlled with larval sprays.

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[1]State Entomologist, New Mexico Department of Agriculture, Albuquerque, New Mexico.

Tiger Moths. Hairy brown and yellow caterpillars up to 1 and 1/2 inches in length when full grown. They are active during the winter and early spring months when other insects are dormant. Young larvae spin silken tents enclosing a branch and then feed within the tent. Older larvae leave the tent and feed throughout the tree. Are sometimes pests in Christmas tree plantings. Tents can be pruned and burned with the larvae inside for control on ornamentals.

Needle Miners. Tiny moths which lay eggs on needles and the newly hatched larvae bore into the needles and eat the needles from the inside. Feeding eventually kills the needles which turn straw colored and drop off the tree. This insect has caused some areas of extensive mortality in New Mexico under natural conditions.

Pinyon-Juniper Wildlife Habitats

Ed Swenson[1]

Good Afternoon

First I want to say that I am not a researcher but a staff biologist. What I read and learn and investigate myself is catalogued into two compartments:

1. Gee whiz! isn't that interesting.

2. Hey, I can use this in my work.

I hope to stay in category 2 and try to inform you of what I have found useful about the P-J type and its associated wildlife - as well as describing some of the biological impacts of type-conversions.

As we know - most P-J or J-P woodlands are grazed - most of them on a yearlong basis. The history of grazing has been long - and has degraded the vegetative community so that most of the type exhibits low herbaceous and woody forage production.

But there's plenty of P-J and there are proven methods of converting the type to grassland with increases of 2 to 5 times for herbaceous production.

Now the P-J type also has a recognized value as wildlife habitat - most frequently mentioned are its values for cover - as well as a source of food - including juniper browse and berries-pinyon nuts - and forage from understory shrubs, forbs and grasses.

The literature, and I should add - the management plans and the EIS's - most often mention the game species which are associated with the P-J type - that is, the mule deer, elk, pronghorn, turkey - etc., for example - the value as winter range for elk and deer is often cited - and we read that 1/4 of the annual Arizona deer harvest is in this type.

However - when we dig a little deeper into the knowledge about the faunal characteristics of P-J we find that while there are a great many species which use the habitat seasonally - there are FEW OBLIGATE species - and these are the pinyon mouse, pinyon jay, plain titmous and lead colored bushtit - species that do not turn on a lot of people.

So it's been the occasional users, the seasonal users - about which most of the informati is available - and at the risk of losing you - these characteristically include - the large ungulates - mule deer, elk, pronghorn, bighorn sheep, the feral horse and burro - the lion, coyote, bobcat, weasel, gray fox, porcupine, th woodland cottontail, and black-tailed jackrabbi in winter, deer mice, pocket mice, least chipmunk, rock squirrel, several woodrats, the herp horned lizard, red-spottedtoad, fence lizard, and western diamondback rattlesnake.

There has been a little more attention give to associated bird species - we know of the ver reliable food source in the juniper berries - and the less reliable but highly attractive pinyon nuts - which bring in the band-tailed pigeon, turkey and the blue grouse at the highe elevations.

Breeding use and summer use is high - reflecting the value of this pygmy forest as an ecotone between the vast grasslands and the sharply elevated timber types.

Among the raptors we find that the ferruginous, swainsons, red-tailed and sparrow hawks and the great horned owl will nest in P-J

Characteristic summer users include the broadtailed hummingbird, ash-throated flycatche say's phoebe, canyon wren, brown towhee, night hawk and poorwill.

During the winter months we find that a ne assemblage of birds will move into the P-J including the mountain bluebird, mountain chicka white breasted nuthatch, house finch, scrub an stellars jays, robins, and loggerhead strike.

Not a lot is known about the food relation of many of these animals - however, the role o wildlife in seed dispersal is often mentioned with the coyote, cottontail and several bird a rodent species being the culprits - I can atte to the heavy utilization of juniper berries by coyote - scats contain more berry than animal hair - and at long distances from juniper trees

[1]USDA, Soil Conservation Service, Albuquerque, New Mexico.

As expected - the food relations of big game species are best understood - generalities such as - "mule deer use Rocky Mountain juniper browse in the winter 'and' - elk use P-J primarily as cover, but eat the herbaceaous understory" - are commonly stated. And probably for browsing wildlife - the winter forage from woody plants IS THE major value of P-J habitats.

The role of late-winter and early spring green forage - the cool season grasses and early forbs - are often mentioned as a plus for deer and elk - and proposals for conversion projects make this point. But it remains unclear if this new source leads to additional use - while it is abundantly clear that winter use of seeded clearings is insignificant.

In reviewing management plans and EIS's for P-J conversion proposals - there is usually a statement made - which I will paraphrase - "the habitat diversity resulting from project X will result in a complex that is more suitable for big game animals and many birds" - and the new edge effect and improved vegetative diversity are normally mentioned.

The values of P-J thinning (or stand reduction) usually involving grass seedlings - also comes in for equally speculative and optimistic statements about anticipated benefits to wildlife - broadly to Big Game Species.

Let's look to some of the pertinent studies to evaluate these statements. - Studies of mule deer food habits demonstrate that the use of grasses is low and they are not utilized at the critical times of food shortages or when staple diet items are low in nutritional value. - Mule deer do not starve to death on P-J habitats in the spring or summer. A 1975 report by New Mexico Game and Fish at Fort Bayard gives us some insight.

They used tame deer - measuring bite count within a fenced enclosure - The pasture had a long history of livestock exclusion - good grass-blue & sideoats co-dominate with P-J canopy averaged 60 percent - going down to 10 percent in open parks. There were 189 plant species occurring - and 90 of them were utilized - but most interesting was that 90 percent of the annual diet was made up or arranged in descending order of utilization.

1. Mountain mahogany
2. Grayoak
3. Birdsbill day flower
4. Morning glory
5. Spiderwart
6. Deer vetch

No grass species!! The use of grass was highest in the spring with 1.6 percent of the diet - and less than 1 percent during fall and winter, while browse made up 92-99 percent in fall and winter - and 42 percent in summer.

So we must look again at values assigned to P-J type conversions for mule deer.

Studies of cause-effect in P-J conversions are few - and those available were aimed at Big Game. - The Utah Cooperative Wildlife Unit has studied three areas starting in 1959 - each area had been seeded to crested wheatgrass.

After determining deer days of use - by pellet group method, they concluded - one was higher, two the same, one lower. Using the same techniques they evaluated 16 conversions - rating them as 6 beneficial, 9 detrimental, and 1 no effect to deer.

In Arizona - McCulloch found no significant differences - P-J conversion areas were NOT improved as deer habitats. Those areas which did have exceptionally higher deer use were - small in size, excluded from livestock, had low tree kill, no slash removal, no seedings. These factors would probably rate the conversions as failures by most agencies!

Nevada reported on 4 conversions - deer use increased on 1, decreased on 1, and did not change on 2.

New Mexico Game and Fish reported in 1974 on Fort Bayard that elk and deer use was highest on undisturbed P-J, next on partially cleared, and lowest on total tree removal areas.

I will not go into the Fort Bayard studies done by Hudson Reynolds and others - you probably all are familiar with them - except to say that the big contribution made was to provide some factual basis for modifying type conversions in the attempt to limit habit degradation for deer and elk.

Studies of small mammal populations show initial increase in numbers for 3 years - then leveling off. Species dependent on trees (the pinyon and brush mouse) declined. Cleared areas support 40 percent higher rodent densities than natural P-J.

The response of the woodland cottontail - (*auduboni*) to type conversions showed their dependence upon a tree canopy or slash. Clean clearings lost this animal.

These studies indicate that conversion to grass has not been uniformly beneficial to mule deer - but also suggesting that elk probably benefit more.

One key ecological principal appears - wildlife diversity and numbers do not increase when vegetation diversity is reduced.

It's also evident that we frequently do not know, or cannot predict, just what the wildlife responses will be.

Here I would like to refer you to the 1971 Publication - "Game Range Improvement in New Mexico" put together by Sam Lamb and Rex Pieper under the auspices of the New Mexico Interagency Range Committee. Modifications in planning P-J conversions are suggested:

1. Leave at least 25 percent natural, particularly rocky points, ridges, and slopes over 15 percent on NE exposure.

2. Leave older, large crowned pinyons.

3. Leave 25 tall shrubs/acre.

4. Clear in strips no wider than 1/4 mile, with uncleared strips no less than 1/8 mile.

5. Add variety to seedlings.

6. Manage livestock.

I imagine that most agencies today are following these modifications.

About three years ago I decided to try and determine what the responses of wildlife had been to P-J conversions done here in New Mexico. My method has been to select ranches on which clearing had been done - find other pastures with similar soils and range sites that were uncleared, and compare. This is done by walking one to two mile belt transects and recording all animal signs in a 6 foot wide band. These transects are walked four times each year - in the four seasons. Comparisons are also made between heavy forage utilization and proper utilization operations.

Data has been collected for transects on four ranches as well as the Cibola and Santa Fe National Forests.

Without reciting a lot of raw data - let me very broadly give you some indications.

First - similarly to the research results, I found that type conversions do NOT greatly improve wildlife diversity or numbers.

Second - deer use is reduced, rodents increase, cottontail leave, black-tailed jackrabbits increase, ant colonies increase.

Third - the natural P-J has wider diversity and higher individuals of bird species - except sometimes during the winter months the seeded clearings will have a large number of a single flocking bird species.

Fourth - it is evident that those P-J stands which have not been overutilized - which have a broad composition of shrubs, forbs, and grasses provide the best overall wildlife habitat - that is - more species, higher numbers, and yearlong users.

My recommendation is that we need to learn more; and until we can be more reliable in our information - we should not condone the sweeping generality that P-J type conversion is good for wildlife - as it appears that most often, it is not.

A Comparison Between Grazed and Ungrazed Juniper Woodland

Clay Baxter[1]

An ungrazed mesa was found 2 years ago southwest of Williams, Arizona. It has an elevation of about 5,980 feet and contains about 10 acres. It is totally inaccessible to livestock. Cottontail rabbits abound on the mesa. The surrounding vegetation is juniper woodland, containing an overstory of Utah juniper. Precipitation averages 10-12 inches.

During the past 10 years I thought blue grama to be an important forage species in the woodland type. Many people say that blue grama has been the salvation of the rancher here in the Southwest. I beleive this ... because, without blue grama most of the ranches in the woodland zone would be out of business since 99 percent of the desirable grass species that used to be there cannot be found - they were grazed out years ago! After seeing this mesa, I fully understand what we have done to the woodland zone.

What I am talking about does not necessarily pertain to all woodland areas in the southwest; for I have seen some that are not in too bad of a condition. But, it does pertain to a lot of range that I have seen. And, I fully expect that the comparison also pertains to most of the desert and semi-desert range found in the southwest.

This ungrazed mesa is an excellent area to compare with grazed rangeland in the woodland zone. In most cases, the mesa does not represent the "potential" of depleted ranges because their "potential" has been lost through the loss of top soil, the loss of soil fertility, the loss of a seed source, and soil compaction.

Today I would like to share with you the things that I have found and observed relative to this ungrazed mesa. I will compare:

1. Forage composition and its relative production

2. Management practices that have altered range resources

3. The condition of browse plants and

4. Soil conditions, as found on the mesa and on nearby grazed range.

I first visited the mesa in March of 1975. I was conducting a range re-analysis on an allotment and had been riding through typical juniper woodland in most of our range. Some of the woodland has blue grama with a little sideoats grama and galleta scattered throughout. Other areas have been completely denuded to the point where practically nothing other than Utah juniper exists. The rock cover you see on the top of the ground is the result of churning action of Vertisol soils. These pictures were taken in March, and in March very little green forage (other than some cool season growers still found in cactus or dense brush) can be found in the woodland zone - OR so I used to think before seeing this mesa. I suppose I thought the cool season grasses normally grew where I saw them. This is true, but not by choice! Two things went through my mind when I first saw this mesa: 1.) Look at all the green grass and 2.) Look at all the Beargrass (supposedly an Invader species).

It is obvious that there is a lot of green grass present in the vegetation seen here. Both mutton bluegrass and squirreltail make up over half of the composition on this mesa. This is obviously very impressive.

I really wondered about the Beargrass since it is not rated very high in our vegetation scorecards. (Decreaser for a Trace, 5 percent is Increaser, and balance as an Invader.) I asked a professor from N.A.U. (L. Fitzhugh) to visit the mesa and asked him about the Beargrass. He thought perhaps, that fire and grazing may have contributed to the loss below the mesa of Beargrass. There is not much found below the mesa. Beargrass, apparently, is not fire tolerant. (Light could be a cause too) Past fire history, as well as livestock and wildlife grazing probably has contributed to the loss of Beargrass. Livestock and wildlife were forced to graze Beargrass as green forage became more scarce. (Rodents will also utilize the leaves for nest material.) Consequently, Beargrass has just about disappeared from the grazed range below the mesa. As fire reduced the Beargrass cover, it was also important for keeping juniper from invading the open grasslands. As grazing reduced the grass cover, fire could not spread through the grass, killing the small invading

[1]USDA, Forest Service, Williams, Arizona

junipers. Also, the reduction in grass cover reduced the competition factor with juniper, allowing juniper to invade the grassland more rapidly. This competition factor probably is the major reason for the lack of juniper on the mesa since fire probably has not had much influence on this isolated piece of land.

I decided to put a permanent transect on the mesa to measure the vegetation. I put in one Parker Three Step transect. Ten species were tallied in the composition based on this transect. In addition, twenty other species were found on the mesa. Undoubtedly, there are other species present that have not been observed. Most of these species (Fourwing saltbush, black grama, vine mesquite, squirreltail, mutton bluegrass) cannot be found on the grazed range below. Range condition, based on the transect, is a low good, while it is a low poor to very poor elsewhere on this allotment.

I read eleven clusters on the allotment the same year. I compiled the data as seen here.

Table 1.--TRANSECT SPECIES COMPOSITION

Species	Relict Mesa	Continuous Grazing	Rest Rotation Grazing
Pofe	45%	0	25%
Sihy	15%	0	10%
Bocu	20%	3%	8%
Bogr	7%	77%	35%
Hija	3%	7%	10%
Muto	0	8%	2%
Forbs	10%	5%	10%
% Bare Ground	8%	65%	25%

There are three things that stand out to me here. ONE: Pofe and Sihy are cool season grasses and the composition on the mesa had 60 percent of these two species. Cool season species are very important in the fall and spring for both livestock and wildlife. Without them on the range, the animals are forced to graze browse plants for a longer period of time, often to the detriment of the browse plants.

TWO: Very little blue grama is found on the mesa while it is dominant on the grazed range. There is on 7 percent on the mesa while it is 77 percent below. It is very obvious that forage production will be higher on the mesa (900-1,000 pounds, air dried) than below (0-200 pounds).

THREE: Only 8 percent of the mesa contains bare ground while 65 percent below is bare ground. This is only on the transects. . .the mesa probably has less bare ground while the grazed range has more based on visual observations. This difference leads to obvious detrimental effects on the land - increased erosion. The effective ground cover on the mesa was found to be 97 percent on the mesa and is between zero and 16 percent below.

These differences are rather startling. The grazing history below the mesa was with cattle being grazed every winter without any management. There has been no fall or spring rest which is important to both the cool season grasses and browse plants. I decided, then, to see what has happened on another allotment with similar soils and similar precipitation but where management with proper stocking has been practiced for about 20 years. Fortunately some transects were established on this particular allotment prior to the establishment of a deferred rest rotation grazing system. The readings for one transect can be seen here:

Table 2.--COMPARISON BETWEEN TRANSECT READINGS FOR A THREE PASTURE DEFERRED REST ROTATION GRAZING SYSTEM

Hits on	1952	1957	1967
Decreaser	20	10	19
Increaser	39	60	111
Invaders	3	1	7
Rock	76	62	53
Litter	50	63	40
Bare Ground	112	104	70
% Cool Season Grasses	18%	16%	35%

The middle reading was about the time that management was initiated. The decreaser species had started out of the picture by 1957 while the increasers went up. Bare ground showed little change. Following 10 years of management with what appears to be proper stocking, the decreaser species improved as did the increasers. Bare ground showed a decrease of about 30 percent.

Some people will say that this change is due to lack of precipitation prior to 1957 and an increase after 1957. Moisture was slightly higher after 1957, BUT other transects on range being grazed under a continuous grazing system without rest or deferment showed little change or a downward trend during the same period of time.

Now, let's go back and compare species composition between the ungrazed mesa, the grazed range under management, and the range being grazed without management. We still have a 35 percent composition of cool season grasses on the range grazed properly. While we do have a 35 percent composition of blue grama, it is far better than the 77 percent found on the continuously grazed range. The rest rotation grazing system has allowed mutton bluegrass, squirreltail, and western wheatgrass to increase in the composition, as well as improving both plant vigor and plant density. The percentage of

bare ground is not so high either. Soils on the properly managed allotment are more stable and will improve faster than will sites on the allotment being grazed without proper management.

In addition to differences between grasses, one can see quite a difference in the condition of browse plants found on the mesa and on the range open to livestock grazing. Shrub live oak, mountain-mahogany, cliffrose, and fourwing saltbush can be found on the mesa. They have well developed, open crowns. They reflect plenty of leader growth. The plants on the open range are typically very heavily hedged with little leader growth. Some stands are very decadent. All reflect heavy utilization. When the more desirable browse species start to receive extreme use, the less desirable species such as algerita, hop tree, skunkbush, and shrub live oak start to reflect use.

Everyone says that livestock condition is a reflection of range condition. This is a picture of a cow that is not in poor shape. The range she came from looks almost like the corral she is standing in. It is pretty bad, obviously. The dark object seen in her mouth is a piece of black plastic pipe. She will eat what is available. Given some supplement, she can stay in good condition. However, I don't believe that we want our rangeland to look like this corral even though some do .....

One might question if there are soil differences that would explain the differences in vegetation found on the mesa and below. I asked our soil scientist to see what kind of soil was on the mesa and to compare it against what they found below (a soils analysis was made previously on the allotment around the mesa. They found the soils to be very similar in that they are moderately deep 20-40"), fine textured clay and clay loam soils forming on basalt parent material. They have large quantities of rock in their profile. The clay fraction is dominated by montmorillontic clay. The taxonomic classification is *typic argiustoll, clayey-skeletal, montmorillonitic, mesic,* with *vertic* and *lithic* integrades. This is where the similarity ends. Soil compaction is dominant on the grazed range but is not present on the mesa. There is little or no soil structure on sites below the mesa while soils on the mesa exhibit strong granular structure on the surface horizon, and moderate to strong subangular blocky structure in subsurface horizons. The compaction found below the mesa produces negative soil properties such as increased soil erosion, decreased water infiltration rates, unbalanced soil atmosphere, and reduced soil fertility causing an overall reduction in soil potential.

In summary, what we have seen here today cannot be fully appreciated without actually seeing the mesa in person. Pictures do not give it justice. While the relict mesa is the best rangeland I have ever seen in the juniper woodland - it does not reflect the true potential of the land found in the woodland around the mesa. This is because past history has reduced the site potential through soil and vegetation degradation. It will never return to the potential it once had. But, through proper livestock management and range development, I believe the range can be improved over what it is at the present. The longer the woodland continues to be abused, the lower its potential will be and the longer it will take to reach that potential.

Product Potential of Pinyon-Juniper Woodlands

Peter F. Ffolliott[1]

In general, the pinyon-juniper woodlands in the Southwest are normally considered of less commercial value than the saw log forests of higher elevations. However, ever since the earliest days of Spanish exploration and settlement, the woodland species have been a source of fuelwood, posts, poles, and even some food (Fogg 1966, Hamilton 1965, Randles 1949, Reveal 1944). More recently, these species have gained attention as a potential source of raw material for paper, particleboard, charcoal, extractives, and novelty items.

The purpose of this paper is to describe some of the physical properties of pinyon and juniper tree species, specifically, how these properties determine woodland product potential. Much of the material for this paper has been gleaned from a larger, more detailed report on the physical characteristics and utilization potential of the pinyon-juniper woodlands (Barger and Ffolliott 1972).

WOOD PRODUCT DETERMINANTS

Opportunities for utilizing the pinyon-juniper woodland species depend, in part, upon such physical properties of the woods as weight or density, mechanical strength, shrinkage characteristics, and visual features (i.e., texture and color). Some knowledge of these physical properties and their variability is a necessary requirement for evaluating utilization potential.

Mechanical strength characteristics are important for uses in which wood members are, or may be, placed under load: posts, poles, ties, and structural timbers, for example. For use in furniture, novelties, or smaller turned or shaped products, hardness, texture, color, fragrance, shrinkage, and finishing characteristics may be of primary importance. Physical characteristics such as density and fiber length affect the yield and quality of chemically derived products, including pulp and charcoal.

The characteristic form and size of trees also help to determine the uses for which the wood may be suitable. Relatively large, uniform stems (i.e., ponderosa pine and Douglas fir) are required for the production of standard lumber, large timbers, or commercial poles. Unfortunately, the pinyon-juniper woodland species do not generally produce stems suitable for such products. Many other products can be produced, however, from the smaller, more irregular stems due to the unique physical characteristics (i.e., fragrance and color) which are common to pinyon and juniper trees.

SPECIFIC GRAVITY

Specific gravity or density is the simplest and most useful single index to the suitability of wood for many uses. Specific gravity is closely related to the mechanical strength of wood and determines, to a large extent, the yield of products such as pulp and charcoal. In addition, it provides a means of estimating strength, shock resistance, and hardness. The variability in specific gravity also indicates, to some degree, the variability to be expected in associated physical properties.

To obtain a measure of specific gravity for pinyon and juniper trees in the Southwest, full length increment cores have been collected from a random sample of approximately 50 trees of ea major species (Barger and Ffolliott 1972). The sample represents a range of site and growth conditions that extend from the ponderosa pine woodland species intermixture above to the chaparral shrub zone below.

The woods of pinyon and juniper tree specie contain appreciable quantities of extractive chemicals. Since most strength characteristics and product yields are considered a function o cell wall material, specific gravity based on extracted wood may be a better index of such properties. Therefore, to determine extractiv content and extracted specific gravity, extrac tives were removed from the sample of incremen cores. An ethyl alcohol-benzene solvent and hot water were used successively to remove mos of the extractives.[2] Specific gravity of piny Utah juniper, and alligator juniper was then determined for the cores before and after extraction (Table 1) by analytic procedures

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[2]Increment core extractions were performed by procedures developed by Glenn Voorhies, formerly with the School of Forestry, Northern Arizona University, Flagstaff, with extraction in the NAU Wood Technology Department.

developed by the USDA Forest Products Laboratory (USDA Forest Service 1956). Specific gravity is a direct measure of the density of wood, which is normally expressed in pound per cubic foot of unextracted wood.

Table 1.--Specific gravity of unextracted and extracted increment cores of woodland species.[1]

Species	Unextracted			Extracted		
	Range		Mean	Range		Mean
	Maxi.	Mini.		Maxi.	Mini.	
Pinyon	0.624	0.430	0.506	0.580	0.405	0.484
Utah juniper	.682	.439	.511	.605	.390	.466
Alligator juniper	.533	.372	.453	.486	.356	.426

[1]Based on ovendry weight and green volume.

Density is one of the properties of wood that affect the yield of pulp. Generally, the denser woods yield more pulp per unit volume of solid wood processed. Both pinyon and the junipers are relatively dense compared to other western softwoods, averaging 10 to 20 percent heavier than ponderosa pine, for example.

All of the pinyon-juniper woodland species are suitable raw material for charcoal. As all wood is about 50 percent carbon, charcoal yields will generally be proportional to the density of the wood. Denser species, such as pinyon and juniper, are often preferred since charcoal yield per unit of wood volume will be greater.

STRENGTH AND RELATED PROPERTIES

Strength properties, which indicate how well a wood member resists a variety of loads or forces, can be determined directly through tests of small wood samples or can be estimated indirectly from specific gravity. Strength characteristics determined from actual mechanical tests (Table 2) are available for pinyon and alligator juniper (Markwardt and Wilson 1935). These test values may also be used to calculate working stresses, load-carrying capacities, and similar values.

Table 2.--Strength properties of the air-dry wood of three woodland species (Markwardt and Wilson 1935).[1]

Property	Unit of Measure	Pinyon	Alligator juniper
Static bending strength:			
Stress at proportional limit	Lb/sq. in	5,600	5,400
Modulus of rupture	Lb/sq. in	7,800	6,700
Modulus of elasticity	M lb/sq. in	1,140	650
Total Work	In.-lb/cu in	6.1	---
Compressive strength:			
Maximum crushing strength parallel to grain	Lb/sq. in	6,400	4,120
Stress at proportional limit, perpendicular to grain	Lb/sq. in	1,520	1,700
Hardness:			
End	Lb.	920	1,290
Side	Lb.	860	1,160

[1]All values are adjusted to a uniform air-dry condition of 12 percent moisture content.

Index values describing major strength and physical properties may be useful in comparing the properties of one wood with another or in choosing a wood outstanding in some particular property. For example, index values for pinyon, alligator juniper, and, for comparative purposes, ponderosa pine (Table 3) are based on combined strength values representing each of six major properties (Markwardt 1930). Using these data, it may be possible to weigh the advantages of one woodland species against another or those of a woodland species against a tree species of assumed higher commercial value, and then select the species with the most desirable features.

Table 3.--Average comparative index[1] of properties of the clear wood of selected woodland species and two common commercial species (Markwardt 1930).

Property	Pinyon	Alligator juniper	Ponderosa pine
	Comparative index		
Bending strength	60	63	65
Compressive strength	75	76	69
Stiffness	108	60	112
Hardness	73	107	41
Shock resistance	65	79	58
Volumetric shrinkage	99	73	97

[1]The numbers are index values based upon a weighted combination of specific strength values related to each of the six essential physical properties. Strength tests of both green and air-dry material were used; the final index values represent a condition of approximately 20 percent moisture content.

Many strength and associated physical properties of wood are closely related to specific gravity. As a matter of fact, empirical equations expressing the relationships of specific gravity to other physical properties have been developed by the USDA Forest Products Laboratory (Markwardt 1930, USDA Forest Service 1956). Since these equations are based on a large volume of source data, predicted strength values may be more reliable than actual strength tests carried out on a small number of samples. Although specific gravity of unextracted wood is commonly used in the computations, values for extracted wood may yield more accurate results. Therefore, strength values based on specific gravity of both unextracted and extracted wood have been calculated and reported (Barger and Ffolliott 1972) for the major pinyon-juniper woodland species in the Southwest.

FACTORS AFFECTING STRENGTH

Strength values are based upon, or calculated for, clear wood specimens. Defects such as knots, decay, or irregular grain will affect many, but not necessarily all, of the strength properties of the wood. For example, knots have little effect upon compressive strength or stiffness.

Strength may also vary due to growth rate, growth conditions peculiar to the tree or locality, or any other factor that influences specific gravity. Strength may even vary between trees of the same species growing in the same locali as demonstrated by the range of specific gravi often encountered in a small geographic area (Table 1). For many species, specific gravity also decreases with the height of the tree, resulting in stronger wood near the butt of th tree, and weaker wood near the top. Also, juv nile wood near the pith is often more rapidly grown and less dense than wood from other part of the tree. Finally, both the pinyon species and the juniper species that are common to the Southwest hybridize occasionally, adding to th possibility of inherent variation due to genet strain.

Moisture content has a pronounced effect up most strength properties, as indicated by comparative strength values for green and air-dry wood. Most strength properties increase rapi as wood dries below the fiber saturation point although the various strength properties are not equally affected. Average variations in physical and mechanical properties due to ran variation in a species, and due to changes in moisture content, have been estimated and reported (Barger and Ffolliott 1972, Markwardt Wilson 1935) for many of the pinyon-juniper woodland species in the Southwest.

SHRINKAGE CHARACTERISTICS

Wood shrinks when it dries below the fibe saturation point of 25 to 30 percent moisture content. Normal wood shrinks a substantial amount transversely, general expressed as rad (across rings) and tangential (parallel to ri shrinkage. Larger differences between radial and tangential shrinkage indicate a greater tendency to check and cup during drying. Per cent shrinkage values from green to oven-dry condition for pinyon, alligator juniper, and, for comparative purposes, ponderosa pine (Tab 4) are nearly twice the shrinkage that will occur between green and an average air-dry condition of 12 to 15 percent (Markwardt and Wilson 1935).

Table 4.--Shrinkage characteristics of the w of selected woodland species and ponder pine (adapted from Markwardt and Wilson

Species	Shrinkage property		
	Radial	Tangential	Volumetric
	Percent		
Woodland:			
Pinyon	4.6	5.2	9.9
Alligator juniper	2.7	3.6	7.8
Ponderosa pine	3.9	6.3	9.6

CONCLUSIONS

The general physical properties of pinyon and juniper trees in the Southwest do seem to indicate opportunities for increased use of the woodlands in terms of wood product recovery. It is conceivable that, in addition to the traditionally derived products such as fuelwood, posts, and poles, the pinyon-juniper woodlands may provide a sizable wood fiber resource for new products including pulp, particleboard, charcoal, and extractives. Of course, whether or not these potentials are realized depends largely upon the availability of suitable market outlets, along with other economic considerations such as efficient tree harvesting and wood processing operations.

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What Is Known and Not Known About Pinyon-Juniper Utilization

Glenn Voorhies[1]

The absence of commercial utilization of the Pinyon-Juniper woodland resource is difficult to understand, particularly so for those individuals who are not familiar with the characteristics of the stand components.

The stem form and board foot volume per acre detracts from a profitable saw log operation. The possibility exists, however, of harvesting selected trees of good form with sufficient bole length to produce lumber or other products for a specialized market. If logs from 3 feet to 8 feet long and 8 inches and larger in diameter are available, varying product potential exists.

Manufacture to lumber or cants on site can proceed with a portable bolter sawmill or by a chain saw filed for ripping. In the latter case, the log can be held firmly in a frame and the chain saw, with a six foot bar, made to ride on a rolling carriage with the frame acting as a guide. Preferred by some operators, a small flat-bed truck with a power take-off boom will load and haul the logs to a permanent mill site. The sawn lumber, in thickness up to 8/4, can be successfully air dried to 10 percent moisture content provided the stock is not exposed to a very low relative humidity. Limited tests indicate 7/4 Juniper may be dried in 60 hours or less when temperature in excess of 220°F. is used. For furniture, panel stock and novelties, the moisture content of the wood must be reduced to 6 percent or less in order to prevent checking in use.

Deep chipped grain can be avoided only by using a sanding surfacer on knotty stock. The knots are rather soft and sand easily. A cutter head surfacer is satisfactory for clear, straight grained wood, even when finger jointed.

Examples of richly colored wall paneling, furniture, especially tables, selling on the retail market up to $600, lamp blanks and numerous novelties can be found at specialized wood working shops.

A parallel to this type of utilization can also be found in Southern Arizona where Mesquite lumber and veneer is produced and fabricated into a line of furniture as well as custom products.

Juniper can also be sliced to veneer thickness from moist hot flitches.

Another attribute of Juniper is the durability of the heartwood as exemplified to the various fungi-toxic extractives present in the wood. These extractives are the source of the aromatic odor, found to varying intensity, in the heartwood, of all Junipers.

The extractives from both the wood and needles of Juniper and Pinyon Pine have been studied by many investigators. From the extractives of Utah Juniper, 12 or more individual compounds have been identified. The compounds which make up the extractive content may be useful in medicine and are a basis for perfumery, are used in cleansing compounds, microscopy and various industrial uses.

The yield of extractives from operations in the "Cedar Breaks" area of Texas are reported to be from 2 percent to 4 percent based on the over dry weight of the wood.

The most recent investigation of Pinyon-Juniper extractives known to the author is that by Dr. J. E. Simpson of the Small Business Administration in Washington, D. C. This work took place almost as a corollary of the Pine stump wood investigation. The yields, without a breakdown of the chemical compounds, were found by the Olustee Florida Naval Stores laboratory to be as follows:

Item	Utah	Allig	Rocky Mt	Pinyon
% Moisture Content	38	31	9	29
Distilled Oil				
Gallons/Ton	2.1	3.0	9.0	1.7
1 /Ton	15.1	21.	64.8	12.2
Acidic (Rosin-like)				
lb./Ton	67.2	87.3	113.5	43.5
Total	82.3	108.3	178.3	55.7
Percent	4.1	5.4	8.9	2.78

Leaf oils and extracts are not included.

Dr. Simpson remarked that "the yields were not sufficient to justify an operation for extractives alone." Additional products from the residuals need to be investigated.

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Field chipping of the entire tree has been suggested as a method of harvesting Juniper on a clear cut basis. Mechanized felling with shears, grapple skidding of the bunched stems to a portable field chipping unit would produce whole tree chips. The chips might then be transported to a central stock pile for subsequent debarking. Such chips might then be extracted, used for pulp or compacted into pellets or fuel logs by using something like the Hausmann briquette machine. In the latter case, the chips would have to be dry to 10 or 12 percent and further hammermilled.

Another alternative for chip use is pulp manufacture. Experimental sulfate pulp has been made from Juniper but of somewhat lower quality than that made from ponderosa pine. The lower strength may be, in part, attributed to a shorter fiber length as well as to the extractives. Debarking of either the chips or rough bolts could well be a deterrent to a bark free chip furnish.

The debarking of whole tree chips may soon become a reality as intensive studies are being made to separate the wood from the attached bark.

Wood and bark, especially wood residues, enjoys a continually rising demand for in plant process energy. Studies made by H. C. Mason show that when residual fuel oil sells at $15.00 per barrel, the value of moisture free hogged fuel has a value of about $30.00 per ton, assuming equal burning efficiency. A correction factor must be applied when burning wet hog fuel as a portion of the wood energy value is consumed in evaporating the water in the wood. The heat value for both Pinyon Pine and Juniper is approximately 9000 B.T.U.'s per pound of dry wood when burned at 100 percent efficiency.

Alternative harvesting systems for thick Juniper stands appear to be available. Whether to use a machine such as hypothesized by Koch and McKenzie, or the Nicholson or Morebank whole tree chipping system, would be dependent on cost and the end products envisioned.

If fuel is to be the prime product for nearby consumption, the wood burning steam boiler or the "fluid flame," fluid bed, or similar systems can handle wet hog fuel. On the other hand, the "Energex" system uses only dry, fairly fine comminuted wood as fuel. The latter system is in use at the Navajo Forest Products Industries Particle Board plant at Navajo, New Mexico. The March 1977 issue of Crows Lumber Digest reports on a veneer drying operation in the State of Washington using the Energex burner for heating a direct-fired veneer dryer. The use of wood residuals has resulted in a saving of $477,000 per year over the prior costs of burning propane.

Charcoal production from wood and wood residuals has long been an intriguing concept for disposition of low grade wood at a profit. Whether a charcoal kiln or some type of a rotary mechanism is used, the recovery of char remains at only 28 to 32 percent of the oven dry weight of the wood. Even when the wood comes free, as in residuals, the result may be a marginal profit.

During the 1974 fuel crisis, one Arkansas plant with installed charcoal making capacity did harvest scrub hardwood to produce fuel. The wood gases evolved during manufacture of char have a heat value per cubic foot of about one-half that of natural gas.

The Pinyon Pine potential for multiproduct harvesting has probably not been intensely researched. Currently, lumber and ties, along with the pinyon nut harvest are the prime products of considerable value.

This presentation has not developed any costs and benefit values, nor has it explored market or demand potentials; for the most part, these are unknown quantities. It is fortunate that the Pinyon-Juniper resource can be "stored on the stump" until some of the potential economic uses unfold.

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Management of Pinyon for Ornamentals, Christmas Trees, and Nut Production

James T. Fisher and Jose M. Montano[1]

Tree invasion and increases in tree density pose serious problems to optimum use of the pinyon-juniper type in many areas of the Southwest (Springfield, 1976). Tree removal is expensive, and under recent economical conditions, the more successful conversion attempts just about break even from the standpoint of benefit-cost (Clarey et al., 1974). The sale of conversion or thinning by-products such as firewood, Christmas trees, nursery stock, and pinyon nuts may determine, to some extent, whether a net loss or gain is recorded for the project.

In Colorado, for example, a rancher cleared 200 acres of pinyon-juniper, bulldozed branches from the trees into gullies to prevent further erosion, and broadcast native grass seed over the entire area(Alessi, 1968). Enough pinyon trees were sold to nurseries from Denver and Colorado Springs to pay for removing the brush. Buyers came to the ranch and balled the trees for ornamental purposes.

Pinyon-juniper stands on fairly level terrain and modestly deep soils offer the best possibilities for conversion to grassland (Springfield, 1976). The same stands usually produce trees with growth forms acceptable for Christmas trees and ornamentals.

Removal of pinyon Christmas trees and nursery stock can be combined with chaining or cabling, since these operations effectively kill only trees greater than 10 feet tall (Springfield, 1976). If smaller trees are not removed, release from dominance by the taller trees stimulates growth to the extent that the latter case may become worse than the former.

In addition to reducing tree density, selective thinning of pinyon trees can result in better nut crops. Applications of additional cultural practices to favor nut production might also be financially rewarding.

This paper will include suggestions on how to manage pinyon-juniper stands for Christmas trees, nursery stock, and nut production. The practices discussed here could apply to conversion, thinning, or sustained operations.

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NUT PRODUCTION

Pinyon nuts have been harvested commercially for about 40 years (Little, 1938a). The pinyon nut crop averages 1 to 2 million pounds annually for New Mexico, Arizona, and Colorado, but one year exceeded 8 million pounds (Little, 1941). The better natural stands may yield 300 pounds of nuts per acre during a good year (Springfield, 1976). At the current retail value of $2.50 per pound, value on a per acre basis would be $750.

Because pinyon nuts constitute a regionally valuable crop, more emphasis should be given to practical techniques for stimulating production in natural stands. Before discussing these techniques, it might be helpful to mention the factors thought to strongly influence fruitfulness in pines.

According to Schmidtling (1974), most studies on fruitfulness in conifers point to the fact that positive responses to experimental treatments can be explained on the basis of increased N or amino acid availability at the critical time of ovulate primordia formation, although the importance of carbohydrates cannot be completely discounted.

Schmidtling produced a schematic (Figure 1) showing the interrelationships between the factors influencing flowering in conifers. On the right of the figure is shown the influence of thinning, cone crop, and fertilization on flowering as they affect nitrogen accumulation.

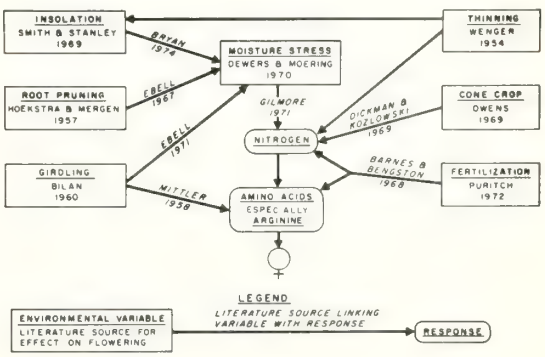


Fig. 1. Interrelationship between factors influencing flowering in conifers (R.C. Schmidtling, 1974)

Thinning reduces competition for nutrients and theoretically should make more N available to the tree. One might argue that the effect may be due to increased moisture supply, but there are studies that would not support this explanation.

Most research on flowering in conifers has examined the role of mineral nutrients, especially the effects of fertilization. Puritch (1972) tabulated 25 references in which fertilizers were applied to conifers and in all but three, fertilizers stimulated female cone production. More specifically, the studies collectively showed the following trends:

1. N is a key component in fertilizer response. For example, in an NPK factorial experiment with slash pine, Morris and Beers (1969) found that N stimulated flowering. Also, it has been shown that good cone producers have a higher proportion of N in their foliage than poor cone producers.

2. N content per se may not be important but the accumulation of amino acids, especially arginine is. For example, Ebell and McMullan (1970) found that nitrate N and ammonium N increased foliar N content and shoot growth in Douglas-fir by similar amounts, but only nitrate N increased female flower production. Free arginine content was greater in nitrate-treated trees than in the others, and appeared to be quantitively associated with increased flower production.

A large cone crop with its drain on nutrients has been associated with periodicity of cone crops (Owens, 1969; Ebell, 1971). It has been shown that developing cones act as sinks for carbohydrate and N reserves at the expense of vegetative structures (Dickmann and Kozlowski, 1969; 1970; Rook and Sweet, 1971). Indeed, large cone crops in conifers have marked effect on radial increment (Eis et al., 1965).

On the left of Figure 1 are those factors that indirectly determine N content through influencing moisture stress. Many studies have shown that moisture stress during the summer results in a better-than-average flower crop the following spring. This suggests that moisture stress, at the time of ovulate primordia formation, promotes reproductive rather than vegetative growth. Circumstantial evidence linking stress with cone production is found in the work of Wareing (1958), who showed that plant water potential was more negative, (i.e., moisture stress was greater) toward the top and toward the extremities of the branches. In these same areas, female cone production in pines is heaviest. Further, water potential was more negative on the side receiving the most sun, which is the side where female flowers are most numerous.

Ebell (1970) suggested a link between wate stress and nutrient status. He showed that fertilizing with nitrate or subjecting Douglas firs to water stress not only elicited simila flowering response, but also brought about similar increases in total N content and free amino acids, especially arginine. Schmidtling (1974) schematic suggests that water stress a N fertilization may increase flowering throug the same metabolic intemediary, arginine or s related N-containing substance.

Rainfall, in general, is positively correlated with flowering. This is because in times of the year other than when ovulate primordia are being initiated the need is for photosynthate production so that carbohydrate reserves are made available when needed. For example, low June and July rainfall would reduce photosynthesis, and thereby, reduce flowering.

In the schematic, one can see that root pruning and girdling can be used to artificia stimulate flowering through increasing moistu stress. Girdling can also directly affect or ganic nitrogen content.

With these factors in mind, one can revie fruitfulness of pinyon and consider how it might be stimulated.

Pinyon trees start bearing nuts at about 25 years, but crops do not reach commercial size until 75 years (Little, 1941). Cones a borne laterally in the axil of a scale leaf near branch tips (Shaw, 1914), although a ra observation of terminal cones has been repor (Lanner, 1969).

Developing cones can be seen in the earl stages as ovulate primordia in longitudinal sections of buds. They can be distinguished from spur shoots in buds by being located on at the tip of the buds, and by having larger and broader bases (Little, 1938b). Buds are formed in August and September, and the cone matures in three years. Because three years are required for cones to develop, an attemp to increase numbers of cones will not affect seed production until at least three years later (Little, 1938b). The first year must especially suitable for production of large numbers of ovulate primordia, and the second and third years must be favorable to growth and maturation of cones and nuts (Little, 19 Nuts are generally produced at intervals of four to seven years.

As suggested by Little (1941), fertiliza cultivation, and irrigation might be used t

stimulate nut production. As shown in Schmidling's schematic, fertilization, especially with nitrate nitrogen, could increase flowering by producing high organic nitrogen levels in the trees. Cultivation and properly timed irrigations could increase the yearly moisture supply available to trees, thus increasing surface area of foliage, crown density, and carbohydrate reserves used for bud formation. An increase in crown density and foliage area may enable young trees to start bearing earlier, since it has been shown for other pines that flowering is related more to size than age (Schmidtling, 1969).

Selective thinning of unproductive trees, also suggested by Little (1940), should increase flowering of the remaining trees. Little (1940) mentioned that some trees are consistently good nut producers, while others are consistently poor. Productive trees usually show immature and old cones in branches, and an accumulation of fallen cones beneath them. Thinning will, therefore, have a two-fold effect: reduction in tree density, and increased nut production.

At the Mora Research Center, studies have begun on fruitfulness in pinyon. Some of the work has been done in natural stands, some will be performed in an experimental orchard of 72 trees (5-10 feet tall) established at the station.

In natural stands basal pruning to a height of five feet was applied to trees 70 to 80 years old with an average height of 25 feet. Ten trees were selected at random for basal pruning and ten trees left unpruned. Pruning was done in February of 1972, and the nut crop was evaluated in October of 1974.

Pruned trees consistently produced larger and heavier nuts. From pruned and unpruned trees, nuts weighed, respectively, 0.32, and .24 g, and had volumes of 0.40 and 2.32 cm^3. Although pruning failed to significantly increase shell-out, pruned trees produced a greater percentage of filled nuts, 99 percent as compared to 84 percent.

The effects observed were related to the effect of pruning on growth of nuts in cones already developing, since the study lasted only two years. Because of its simplicity, basal pruning may prove to be a valuable technique for stimulating nut production. An increase in nut size should definitely facilitate the laborous task of picking and shelling. Pruning could be done during thinning operations.

PINYON CHRISTMAS TREES

Pinyon Christmas trees are harvested from natural stands on federal, state, and private lands. In 1964, pinyons comprised 25 percent of all Christmas trees sold in the six-state-area of New Mexico, Arizona, Colorado, Wyoming, Utah, and Nevada (Sowder, 1965).

In reproduction and immature stages (Figure 2: Bradshaw and Reveal, 1943), pinyon trees possess many of the attributes of a Christmas tree:

1. dense foliage
2. symmetrical shape
3. green color
4. branch angle and limb strength suited for hanging pendulous ornaments
5. natural fragrance
6. good needle retention following harvest.

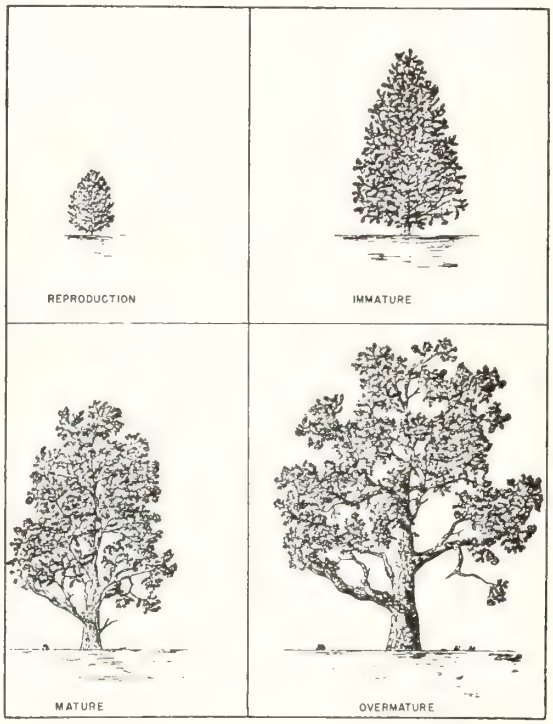


Fig. 2. Maturity classes proposed for Pinus monophylla (Bradshaw and Reveal, 1943)

However, demand for pinyon Christmas trees has declined since 1960 (Barger and Ffolliott, 1972). This may be due to increased competition from artificial and plantation-grown trees and from a reduced supply of marketable trees. Through proper management, pinyons growing on

moderately deep soils can be cultured into saleable Christmas trees, and cut on a rotational basis, if desired.

Cultural techniques include thinning, pruning and shearing, stump culture, and weed control (Jensen, 1972). If the management goal is complete conversion, then these techniques would be applied to trees surviving cabling or chaining. If the goal is to sustain tree production, then regeneration plantings would be needed. Containerized seedlings could be planted under nurse trees in the spring, as suggested by Jensen (1972).

Thinning involves removal of trees in dense stands so that those remaining will receive sufficient sunlight for limbs to develop uniformly on all sides. During thinning, "handles" can be made on main stems of trees by removing branches for a foot or so below what will be the crown base of the tree. These are cut below a full whorl of branches, leaving several branches at the base of the tree for stump culture subsequent to harvest. A year after the tree has been cut limbs begin to turn up and with the exception of one main stem are pruned.

The ideal Christmas tree resembles an inverted cone, wide at the base and tapered uniformly to the tip. Spruces and firs have an acceptable taper of 40 to 70 percent, while pines have a greater taper with an acceptable range from 40 to 90 percent. Pruning and shearing of pinyon trees in natural stands will make them conform more closely to the ideal, so they are competitive with artificial and plantation-grown trees. Pruning involves the removal of dead or defective branches to improve appearance of the tree. The aim of shearing is: to control leader growth so that the distance between shorls is not excessive; induce more branch buds to develop than normally do so; and give the tree the desired pyramidal shape. Because leader growth of pinyon trees rarely exceeds eight inches, excessive distance between whorls is not a problem. Uneven, ovoid, and thin crowns do occur and will benefit from pruning and shearing.

In pines each needle bundle contains a dormant or adventitious bud. If the terminal portion of the stems is sheared at the proper time of year, a number of dormant buds in needle bundles just below the cut will develop into short buds. The result is increased crown density. In single-needled conifers such as spruces, firs, and Douglas-firs, intermediate buds are produced along the terminal stems between each whorl. For this reason, they can be sheared during any season of the year and produce about the same number of branch buds.

In pines the number and size of the branch buds produced depends upon the physiological state of the tree when it is sheared. It is best to prune pines just after height growth has been completed, but before tissues in the stems have completely hardened. At this time the number of large, vigorous buds that devel below the pruning cut will be from two to fou times as great as the number on unpruned stem Pinyon shoots elongate principally during the last of June and continue to elongate during July and August after candle growth has cease Buds are formed in August and September.

Studies in South Dakota (Collins, 1960) and Colorado (Sprackling, 1968) related shear ing date to bud formation in ponderosa pine. These showed that shearing should be done shortly after candle elongation is completed. The Colorado study further demonstrated that shearing should be done after current needles have grown to one-third full length, usually in early July. Also, trees pruned in late summer produced only a few buds so that growth and foliage density was less than that of unpruned trees. Shearing too early in the growing season is, therefore, preferable to shearing too late.

Although no shearing studies have been pu lished on pinyon that we are aware of, certai general recommendations for shaping pinyon ca be derived from the literature.

1. Prior to growing season, prune all double and multiple leaders. This could be done in April.

2. Shear when needles on new candles ar 1/3 as long as last year's needles (usually from June 15 to July 1). Shear leader at a 45° angle. Do not use a horizontal cut.

3. Shape the tree from the top down by shearing the tips of the laterals. Give the tree a conical shape so that the base is no more than 90 percent as wide as tall. Ideal taper should be 40-90 percent. Avoid sheari back to woody tissue, since this may result double or multiple leaders.

4. If the tree is oblong rather than tapered, shear the top in June or early July and the sides in late summer, fall, or winte Growth of laterals will be reduced. Steps 2 may be repeated annually as needed.

5. During final year of marketing, avoi shearing.

Because grading systems developed by the USDA emphasized the slender, tapered form o true firs and spruces, and degraded trees w more ovoid shapes, Kearns et al. (1962) pre pared standards for pinyon Christmas trees.

Pinyon trees are found acceptable under this classification that would have been culled under USDA guidelines. Four form classes are recognized and are considered equally acceptable:

1. tapered
2. triangular
3. oblong
4. round

Within each class, trees may be graded on the bases of color, density, symmetry, and deformity. A premium tree has dense foliage, four good sides, deep green color and possibly a minor deformity; a standard tree has less dense foliage, three good sides, and minor deformity; a utility has only two good sides, generally more open foliage, minor deformity, and possibly some loss of color. Culls do not meet minimal requirements of any of these categories.

PINYON NURSERY STOCK

As discussed earlier, cabling and chaining do not effectively kill trees less than 10 feet tall. Reproduction and immature trees are ideal for nursery stock. Where soils are deep, free of large rocks, and not easily eroded, trees can be dug and sold to offset, somewhat, the costs of conversion.

Pinyon trees can be dug when dormant, usually from late September to April in most areas. The most popular size for large transplants is 6-8 feet, since special equipment is not needed to handle the root ball.

For trees growing on porous soils, digging should be scheduled during months when soil moisture is sufficient to hold root balls together. If this cannot be done it may be necessary to water trees artifically.

Several measures may be taken to improve the quality of trees to be sold and to improve post-transplant survival. Thinning of unwanted trees and weed control will release desirable trees to develop symmetrically. Pruning and shearing can be employed in the same way as that used for producing Christmas trees. Trees that have been knocked down by cabling, but have survived, may be especially appealing after they are pruned to resemble wind-swept trees.

Techniques to increase post-transplanting survival are rarely used, but are highly desirable. Root pruning a year in advance of digging may increase survival. Spraying the foliage with antitranspirants before digging may also help.

Discussions with numerous nurserymen about their tree digging practices have made apparent the need for stronger measures to prevent the spread of pinyon insects and diseases infesting transplants. Very few diggers consult with plant inspectors, forest rangers, or county extension agents before moving trees. Certainly, there is a need to educate these individuals about the serious problems that may arise from transporting infested trees. Of course, transporting infested trees across interstate lines is illegal, and plant inspectors confiscate and destroy truckloads of trees when disease and insects are detected. This type of loss can be avoided as digging crews could identify infested trees.

Transport of infested trees can greatly expand the range of the pathogen and insect pests. For example, the pinyon pine dwarf mistletoe (*Arceuthobium divaricatum*) was moved two hundred miles north of its previous range when pinyon from New Mexico were transported to Colorado.

Management of pinyon stands to keep harmful insect populations at low levels is difficult, primarily because it is difficult to spray the trees with ground rigs. For small acreages the backpack sprayer is economical and efficient. On large acreages an economical method to manage insect pests is to cut down infested trees and use them as fuelwood.

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Forest Practices Needed for the Pinyon-Juniper Type

Raymond R. Gallegos[1]

Thank you Mr. Chairman, Fellow Members of the Society.

One of the highest honors to ever come my way was on January 1 of this year, when the Executive Vice-President of the Society of American Foresters, Mr. Glascock, wrote me to advise me that the council had approved my application for membership in the Society of American Foresters. This is an honor I have looked forward to for the past 15 years.

Although my formal education is not in the field of Forestry, I feel that since I have dedicated 15 years of my life to this great profession, that I am deep rooted and very gladly so. In this context, the one thing that stands out is that foresters, those individuals who have dedicated their lives to the conservation of our timber resources, are men of integrity. They are individuals who are sincere, honest, and who are willing to give total support to their profession.

Thankful and honored am I, of being a small part of this Society. Individuals - professional foresters - such as, Jean Hassell, Yale Weinstein, Erb Kalusa, Tom Borden, Tom Schmeckpeper, Mel Hyatt and countless others, are some of the individuals I work with, and I find that these professionals give 120 percent of their knowledge and of their compassion to help you and I, as individuals, or as a group.

ARE FOREST PRACTICES NEEDED FOR THE PINYON-JUNIPER TYPE?

This is my subject matter for today. To answer this question honestly, sincerely and completely, one must surely explore the benefits that can be derived from this type.

In talking to different individual foresters, many of whom are in this very room, I was not able to get a definite, concrete answer. Many of those individuals support one school of thought, in which they tend to support the eradication of Pinyon-Juniper in support of best range management practices. Then, we have the other school of thought, and that is that Pinyon-Juniper should be left intact, and that stands of Juniper should be properly managed under the best forest management practices.

But, the thing I keep hearing most is "There is not that much information, or studies conducted as to a potential market for Pinyon-Juniper." All of the studies on the Pinyon-Juniper type are in their infancy. There just has not been that much time, effort, or money put into exploring the possibilities of this type.

It is generally accepted that, of the two classifications, commercial and non-commercial, that Pinyon-Juniper falls under the category of non-commercial, and as a result will also take on a further classification of "little value."

In view of this, one could very easily assume, that possibly, the best and only logical way to go would be to eradicate the Pinyon-Juniper type and use these lands for other purposes; namely grazing.

Possibly, the things I want to bring out to you and what follows, may seem rather basic to many of the people here today; however, my approach to this subject was brought about by analyzing "what are the every day problems" and questions that State Forestry personnel deal with in advising private landowners. We must realize that the average citizen is concerned with what is at hand, and one thing for sure, is that small landowners do not want to put too much money into improvements. Why? Simply because they cannot afford it. Their main interest is to learn how to get the most out of their land, without having to put in any more money, or having to wait 5 to 10 years to recover their investment.

So, let's hold on for a minute and explore some of the goods that we do know have come out of this type in the past. What is evident, and what are the known facts that we can come up with to support the continued existence of the Pinyon-Juniper.

For one, the market for Pinyon Nuts is steadily gaining momentum. Just the other day, I walked into a store in downtown Santa Fe to purchase a pound of Pinyon and I was almost

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[1]State Forester, New Mexico Department of State Forestry. Santa Fe, New Mexico

floored when the clerk charged me $3.39 a pound. Knowing the clerk real well, I asked him, "Isn't this rather high for Pinyon?" The clerk advised me that the demand was so high, that he was purchasing in bulk, because by purchasing in bulk, he was able to give his customers a better price.

He went on to say that many of the stores in Santa Fe were selling the Pinyon Nuts at $4.00 a pound. I was not satisfied with just the one source, so a further investigation produced the following:

2nd Retail Source - $3.25 a pound

3rd Retail Source - $3.49 a pound

4th Retail Source - $3.75 a pound (Roasted)

5th Retail Source - $7.60 a pound (Roasted and Peeled)

Of course, the last source is not a comparable source, but who would ever dream that a pound of Pinyon could bring in $7.60 a pound. Surely, if the demand for the Pinyon Nut is increasing to such an extent that the retail price is now approaching $4.00 a pound, then let's again stop and analyze what the Pinyon crop could bring to our economy.

For instance, one of the largest harvests on record was in 1936, when eight (8) million pounds were gathered in New Mexico, and the estimated revenue was $700,000. To calculate what it would bring at today's prices (at $3.50 per pound), would amount to a total of 28 million dollars. Now, we know that the average gathered per year is not eight million pounds, but the average gather per year is estimated at one and a half million pounds. Even at this, it would mean (at $3.50 per pound), that it would bring in $5,250,000 in revenue to Pinyon pickers and processors.

With this much potential revenue in the sale of Pinyon Nuts, one surely must consider this as a factor in favoring a need for forest practices on the Pinyon type.

Also, we find that in Utah alone, approximately 40,000 Pinyon trees are used annually for Christmas Trees. Statistics indicate that there are approximately 60 to 75 million acres of Pinyon-Juniper in a five state area, and those states are Nevada, Utah, Colorado, New Mexico and Arizona. Statistics also indicate that New Mexico and Arizona have at least one half of those acres. One can just imagine the potential available to these two States in the promotion of Pinyon as a Christmas Tree. Also, along with the number, or demand needed, one must also consider the going rate. The last figure I was able to obtain is that a Christmas Tree has been selling for between $2.00 and $3.00 per foot. Let's add another plus in support of proper forest management of the Pinyon type.

Firewood.- I venture to say that 80 to 90 percent of the people in this room have had the experience, or have heard a neighbor or friend complain of the high prices they have been paying for a cord of firewood. The latest figure I was able to obtain is that firewood is selling for between $50.00 to $70.00 a cord.

Virtually every home being built today has a fireplace, and with the ever increasing problem that we are facing in the energy crisis, it is a sure thing, and it is also safe to say that the demand for firewood is increasing in leaps and bounds. Again, I feel very strongly that we should add another plus for proper forest management of the Pinyon-Juniper type.

How about Juniper fence posts? The latest information on this is that they usually start at about $1.50 and some of the better posts are selling for as high as $3.00 each. Many thousands of miles of fence line are being put up annually and, in many instances, the posts used for the fences are Juniper posts. Does this market not deserve at least a small plus in defense of proper forest management of the Juniper type?

Another very important aspect that, surely, has to be considered in the Pinyon-Juniper ecosystem is wildlife. How many hundreds of different species of both small and large mammals and birds make their homes in this system?

There does not seem to be a definite answer to this, as some of the research material will tend to lead you in a certain direction. Then one reads other material which will state just the opposite. For example, here is a quotation that I would like to read to you, and I quote, "Of the many species of wildlife that inhabit the Pinyon-Juniper ecosystem, all or part of the year, few species are considered to be obligate." Another piece of research material stated, and again I quote, "We remain in near total ignorance of the impact of Pinyon-Juniper conversion on the hundreds of vertebrate species influenced by this large ecosystem."

If there is this much uncertainty as to what species do exist and the effect it would have on them, should the system be eradicated? Should we not be real concerned about the wildlife that cannot exist outside this system? And then again, even "IF" and this is a big "IF," the

majority of the wildlife could survive outside the Pinyon-Juniper type, why should we pass rules and regulations to drive wildlife away from a habitat that is native to them?

The point that I want to bring out here is that the Pinyon-Juniper does, in fact, provide food and shelter for many species of wildlife. Simply because some evidence points out that there is a possibility that many species of wildlife can survive in other environments, is not sufficient reason to consider eradication of the type. The Pinyon-Juniper system for many animals and birds is the ideal habitat, let's find ways to satisfy both man and beast.

Another consideration that must be dealt with here, is that of the Endangered Species Act. This act has come about and the rules that govern this are very enforceable, with strong legislative support.

Wildlife must be, it has to be, a serious consideration and the thought of favoring eradication without regard to wildlife would, undoubtedly, be a very serious misjudgement.

In my research for the preparation of this talk, I contacted several officials of the State Game and Fish Department. Their concern, as would be expected, is that proper management be applied. They went on to say that if the stands are, in fact, too dense, sure, open them up for better wildlife utilization, but this does not go to say that they would support complete eradication of large areas of Pinyon-Juniper type.

Many of those game officials also went on to say that the Deer population does, indeed, depend on Pinyon-Juniper and should programs or management plans come about to eradicate large portions or sections of the Pinyon-Juniper type, all of the wildlife that use this type as their habitat would, indeed, be affected.

So, again, all indications in dealing with wildlife living within this ecosystem tend to strongly consider stepping up the process for providing best forest management practices for the Pinyon-Juniper type.

Another approach that I would like to bring out to you for your consideration is, let's examine the signs which indicate a definite need for wood products in the future. One can pick up a newspaper, or sit down to watch television, or turn on the radio, be it at home or in our cars, and what is one of the subjects constantly being discussed? Energy, is it not? This subject is not being discussed only locally, but throughout the entire world. "People are very concerned." The leaders of all nations are being pressured to enact legislation to support new programs for the development of new and better ways to produce one of our most precious commodities - "energy."

Our forests may possibly supply a portion of that precious commodity. There have been some studies conducted along these avenues, yet, studies and pilot programs are barely scratching the surface. However, one thing that is certain is that the demand for renewable resources is getting greater and will continue along these trends with the ever increasing population growth.

Population growth, as is evident, results in the depletion of both our renewable and non-renewable resources. Do we have an answer to produce non-renewable resources? Of course not, so we must rely heavily on our renewable resources. We as foresters, must explore and come up with the necessary guarantee that our nation and all nations of the world are continually supplied with wood and wood fiber, a resource that is renewable and one that should be made available upon demand.

I came across the Dr. Jean Mater paper which dealt with the feasibility study for utilizing sawmill and forest wood residues for the generation of electric power. The results of this study were published in October of 1972, yet to my knowledge, very little action has been taken on the recommendations that were proposed which, in part, are as follows, and I quote, "Our investigation of the feasibility of utilizing wood and bark residues available in North Central New Mexico which will produce electric power, leads us to believe that this is an excellent method of solving two regional problems. Namely, (1) air pollution and (2) energy shortage. We recommend that the regional authority pursue the investigation with a determination to build a power plant, that is, if the conclusions of this preliminary study are confirmed."

Evidently, there is a "bottleneck" that has held up the progress of the forward movement of the construction of the plant, I venture to say a lack of support in obtaining adequate funding. The essential point, however, is that research is underway. New and better methods for the utilization of our wood products will come about.

Demand - can we meet the demand? The emphasis has been in disregarding the Pinyon-Juniper type for other forest types that will produce more lumber and, thus, a greater return for the money invested. Definitely, good common sense will guide us toward this end. But, are we going to be able to completely satisfy our needs in the future by only caring for those types that produce the greater return, or are we going to be caught short? I don't know the

answer to this and, in my opinion, I do not believe that there is any one else who has a correct, absolute, definite answer.

Then, doesn't it stand to reason that we should start preparing ourselves to be able to meet the demands of the people, the demands of the nation, in the best way we know how. Who has the responsibility to assure that the supply will meet the demand? Does it not rest on our shoulders?

The question is, how do we accomplish this by complete eradication of the Pinyon-Juniper type, or by bringing about best forest management practices.

Managing Pinyon-Juniper for Multiple Benefits

William D. Hurst[1]

The 60 million acres of pinyon-juniper in the Western United States has throughout the years provided numerous benefits to people, both local and to those who live some distance from where these pygmy forests grow. It can be accurately said, I believe, that in the settlement and development of the West, products and benefits from the pinyon-juniper complex played a more significant role than did the so-called commercial forest type.

Fuel

The pinyon-juniper type provided heating and cooking fuel for thousands of homes and was the only source of fuel for many of them. For better than half of my life, pinyon-juniper has provided the heating and cooking fuel used in my family. Even today, this species fuels many homes in the rural areas of the western states, and its use is very likely to become more prevalent.

Posts

The "cedar" post fenced the West, and this post is yet the most common on the fence lines of western America. You can prove this to yourself by observing the fence line of the highways and byways of western America.

Forage

The pinyon-juniper type furnishes an extremely important part of the total years supply of forage used by the western livestock industry. The so-called spring-fall range is largely confined to this type and is used about 6 months each year, sometimes more. The type is also the critical winter range for many deer and elk herds and provides a rich environment for many species of wildlife.

Charcoal

Pinyon was the foundation of a substantial charcoal industry in many parts of the west. Thousands of acres were heavily cut to support this business.

Christmas trees

For many people, there is no true Christmas without a pinyon or juniper Christmas tree. Their popularity is growing.

Nuts

Pinyon nuts have been a staple food for Indian people from time immemorial and a delicacy for the white man. They are nutritious and delicious and in demand. Their popularity is growing.

Archeological

Because of its altitudinal and longitudinal location, between 4500 and 7500 feet above sea level, the pinyon-juniper type has been a very hospitable living area since the advent of man. Because of this, pinyon juniper stands are rich in archeological treasures--a value not adequately recognized.

Medicinal

Both pinyon and juniper contain medicinal properties that are very valuable. Although not economically feasible to extract at the present time, they may be competitive in the future.

Pulp

The pulping qualities of pinyon are acceptable but not competitive with other species at present. Both species hold promise for such use in the future.

Naval Stores

Pinyon contains the potential for naval store production but again is not yet competitive.

Ornamentals

The pinyon pine is widely used as an ornamental and this use is increasing.

Fifteen percent of pinyon-juniper type or about 9 million acres is on the National Forests. Of this acreage, the Forest Service estimates that about 2 million acres is on soil types that would respond to thinning or clearing

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effort, primarily to improve forage for livestock and big game. Of this 2 million acres, about 700,000 has been treated in one way or another. I cite these figures because the ratio is likely similar on BLM, state and private land. Not a large percentage of the pinyon-juniper complex lends itself to type conversion.

Both species, pinyon and juniper, are aggressive invaders when man or nature reduces competition on areas adjacent to the pinyon-juniper's natural environment (cite the 1921-1941 and 1958 Grantsville studies). Because of overgrazing and a rigid fire control program, pinyon-juniper stands have "thickened up" in many places.

It is my personal feelings that control of these species should be confined to areas of invasion. These are usually the deep and productive soils where the sought after objectives are most likely to be achieved. Simply because an area would produce more forage if the trees were thinned or removed is not the sole or even the most important criteria for taking such action. A careful multi-disciplinary process is required.

Control or conversion work is usually undertaken in the pinyon-juniper type for four purposes: (1) to increase forage for domestic livestock, (2) to improve watershed conditions, (3) to increase water yield, or (4) to improve wildlife habitat. Most often, increasing forage for livestock use is the initiating force.

When resource conditions and land use objectives indicate the feasibility of pinyon-juniper control, an evaluation or planning process begins. An inventory of vegetation, soils, water, wildlife, archeology, and other resources is developed, coordinated, and evaluated in an environmental analysis. Effort is made to involve throughout the process livestock operators, state game and fish department personnel, public interest groups, and other interested agencies and people. The findings of the environmental analysis and the public reaction to it forms the basis for a decision to proceed or not.

Experience has shown that forage increases in economic amounts can be achieved only on the deeper soils that have been invaded by either pinyon or juniper or both. Areas having a tree density of less than 120 per acre are not treated. Areas having 250 trees or more per acre usually have the greatest chance of becoming a profitable operation.

If increased forage production is the objective, a soil depth of at least 20 inches is required. The more shallow, rocky soils favor browse, and browse will come back if the pinyon juniper is removed. Sandy soils should be avoided when mechanical treatment is applied unless sufficient debris is left on the ground to form a protective mulch. Slopes exceeding 20 percent should not be treated. The grass and browse species seeded should either be native to the area or of proven adaptability.

Research in Arizona has shown that, under most conditions, little benefit can be obtained by removing or controlling pinyon-juniper to improve water yield. The practice is, in my opinion, not justified economically or environmentally for this purpose. Without doubt water yield can be improved in some areas if the overstory is removed but the benefits are small. The cost cannot be justified for water yield alone. Some very limited areas may be exceptio to this rule, but they are indeed scarce.

From the standpoint of wildlife, it goes without saying that what is good for one animal species is not necessarily beneficial to anothe When tree numbers exceed 150 per acre, there is usually a noticeable reduction in understory shrubs. When this occurs, an important food source for deer and elk is adversely affected. The pinyon-juniper type is very important as winter range for these animals, and a reduced food supply at this time of year can be critica for them. Where control or treatment is undertaken, patterns should be carefully planned to create uneven margins and optimum "edge" island and fingers of unmolested cover must be provide for shelter and escape routes.

The economics of pinyon-juniper control has been the subject of many arguments. In the Southwestern Region of the Forest Service, cost have averaged 25 to 27 dollars per acre for a completed job using the tree crusher; this cost includes seed for reseeding. Chaining costs ma be a dollar or two less, but by the time the necessary cleanup and seeding have been accomplished, the difference between the two methods will not be great. There are two other major methods of control--burning and use of chemical but these two methods have not been used much in the Southwest because hot fires are hard to control, and if they aren't hot not many of the trees will be burned. Chemicals can be effectively used in initial control of pinyon-junipe but because of widespread public opposition, they have seen little use.

USDA, Forest Research Paper (RM-128) of October 1974 includes an economic analysis of pinyon-juniper control work on Beaver Creek south of Flagstaff, Arizona. This study shows that a successful pinyon-juniper control projec

should expect an increase in usable forage of 400 to 600 pounds per acre beginning 2 or 3 years after treatment. An average increase of 500 pounds per acre is equivalent to 0.27 AUM's per acre. Using $5.82 per AUM capitalized at 7 percent interest, the benefit from the project was $19.15 per acre. Additional benefits from reduced labor costs and faster weight gains of yearling calves were $4.33 per acre, making total benefits to the project of $23.49 per acre. A quick comparison shows that for even the more successful projects, the margin between benefits and costs is close. Consequently, each project must be examined carefully on its own merits.

The same study concluded that mechanical methods of pinyon-juniper removal are not likely to increase water yield, change peak flows, or change water quality. It also concludes that herbage growth increased following virtually all pinyon-juniper treatment efforts, although there was a great variation in the amount of herbage produced. This study also indicated that response by deer to the Beaver Creek work was neutral.

What of the future of the pinyon-juniper ecosystem? Perhaps no vegetative type has given man so much and been so harshly treated and neglected. Management of the type, with the perpetuation of pinyon-juniper is yet nonexistent. While a small portion of the 60 million acres of pinyon-juniper on the most productive soils can and should be changed to grassland or browse since these lands are extremely productive for forage species, the original stands can best serve man if managed to maintain and encourage pinyon and juniper. If properly managed, these lands can produce substantial volumes of forage while providing many other benefits to man. In fact, no other vegetative type lends itself so well to multiple product management--forage, posts, Christmas trees, nuts, fuel, wildlife habitat.

Perhaps most important of all, the pinyon-juniper type is an attractive part of the western landscape. For this reason alone, it should be perpetuated. Moreover, it is extremely productive and the value of its numerous products need greater recognition.

With a new nursery going up in the Southwest, perhaps greater efforts can be made to manage pinyon-juniper on a substantial scale. I would hope that areas could be set aside, planted and managed for, as a beginning, posts, Christmas trees and nuts.

Systems Approach to Pinyon-Juniper Management

Gene Anderson[1]

Thank you for the opportunity to speak to you today. As stated by Mr. Kolusa, I am replacing Mr. Cary W. Hull on the agenda.

I am new in this area, having newly arrived from California in January. I am quickly learning about P-J management however, and listening to the speakers yesterday has certainly increased my accumulated knowledge.

The systems approach to P-J management is really just an approach which translates the information that we have been sharing these 2 days into language that the average landowner can understand and use. I believe that we have much more information than we realize, if we can only manage to get it into terms for private landowners. As professionals, we sometimes belittle the information that we have. But when we translate it to the public, you would be amazed at how much it seems to be.

Many of you may not be in the position of working with private landowners, so this discussion may seem odd to you; but, P-J management cannot be done on government-owned land alone, and it certainly cannot be done without the public's cooperation.

A management systems approach breaks the problem down into simple terms. In this case we can use three: (1) erosion control, (2) forest management, (3) grazing management.

In the Soil Conservation Service, we stress soil management as a key to using and maintaining all of our resources. The soil management system which can consist of erosion control and maintenance of the litter layer, is an excellent starting point for educating the public as to the importance and complexity of the pinyon juniper community.

The second system, forest management, is a natural, as most landowners are most interested in what to do about those darn trees. We address the subject, but again, we stress the relationship to soil management. Many P-J soils will not respond well to clearing or even heavy thinning, so we built this system on what we learned in designing the first.

The third system, grazing management, may be the most important to some people, but must be handled within the confines of the other two on true woodland soils. As we have seen these last 2 days, the whole resource can be ruined if we allow this system to over-ride the other two.

What is a "Systems Approach?" It boils down to a complete management plan based on research, common sense, and a thorough understanding with the landowner. Using a method such as this that totally involves the landowner is the only way that we will get P-J management on the ground.

Thank you for the opportunity for me to speak to you, I hope to work with you all again in the future.

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[1]Soil Conservation Service, Denver, Colorado

*U.S. GOVERNMENT PRINTING OFFICE: 1977 — 781-679/164 REGION

Aldon, Earl F., and Thomas J. Loring, tech. coord. 1977. Ecology, uses, and management of pinyon-juniper woodlands: Proceedings of the workshop. [Albuquerque, N. M., Mar. 24-25, 1977.] USDA For. Serv. Gen. Tech. Rep. RM-39, 48 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

It is estimated the pinyon-juniper woodland type occupies 33 million acres in the western United States. This vast resource has great potential for social benefits. Our knowledge of the type is summarized in 12 papers in three areas: Ecology of the type, uses and potentials, and management strategies for the woodland zone.

Keywords: Pinyon-juniper, forest utilization

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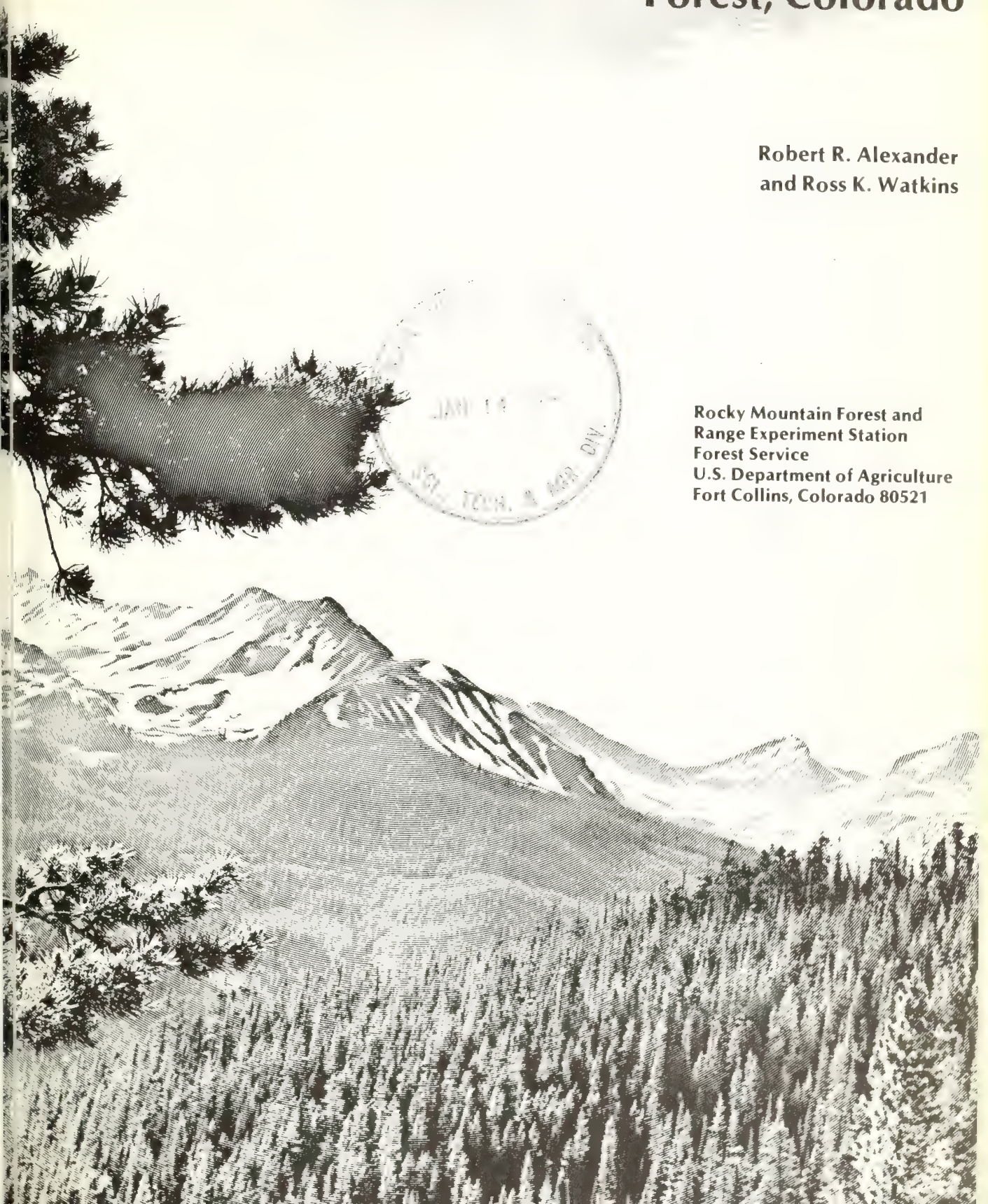
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tmber 1977

The Fraser Experimental Forest, Colorado

Robert R. Alexander
and Ross K. Watkins



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Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture
Fort Collins, Colorado 80521


FORT COLLINS
LOVELAND
BERTHOUD
LONGMONT
BOULDER
DENVER
LONG'S PEAK
ELEV. 14,255
CONTINENTAL DIVIDE
COLORADO-BIG THOMPSON DIVERSION
GRANBY RESERVOIR
WILLOW CREEK RES.
TABERNASH
FRASER
Fraser
EXPERIMENTAL
FOREST
HEADQUARTERS
MOFFAT TUNNEL DIVERSION
BERTHOUD PASS
ELEV. 11,306 FEET
RIVERS PEAK
ELEV. 13

USDA Forest Service
General Technical Report RM-40

September 1977

The Fraser Experimental Forest, Colorado

Robert R. Alexander, and Ross K. Watkins[1]

[1]*Alexander is Chief Silviculturist, and Watkins is Forestry Research Technician at the Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

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THE FRASER EXPERIMENTAL FOREST, COLORADO

Robert R. Alexander, and Ross K. Watkins

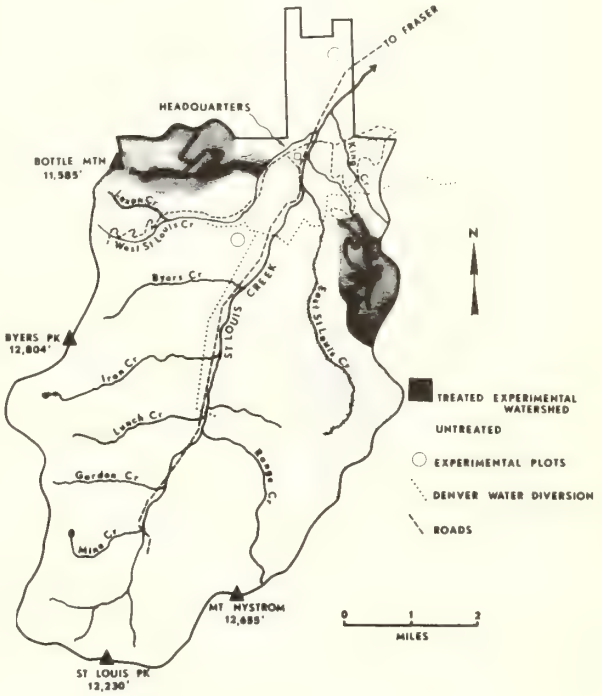
The Fraser Experimental Forest was established in 1937 in the heart of the central Rocky Mountains. This 36-square-mile outdoor research laboratory maintained by the Rocky Mountain Forest and Range Experiment Station is located 50 air miles west of Denver, Colo. The location is well suited to the study of timber, water and wildlife management, and their integration in high elevation subalpine coniferous forests.

In the West, water is vital to life and development. St. Louis Creek, the main drainage on the Fraser Experimental Forest, is typical of headwater streams that are the source of 85% of the annual yield of about 20 million acre feet of water from the Colorado Rockies.

The relationship between water sources in high elevation forests, extensive transmountain diversions, and domestic, industrial and agricultural users is shown in a schematic view of the Fraser Experimental Forest and its surrounding country. The Colorado-Big Thompson transmountain diversion taps the headwaters of the Colorado River and brings water through the 13-mile-long Alva Adams Tunnel to users on the east side of the Continental Divide. The Fraser River transmountain diversion, constructed by the City of Denver to bring water from St. Louis and Vasquez Creeks, crosses the Continental Divide through the pioneer bore of the 6-mile-long Moffat Tunnel.

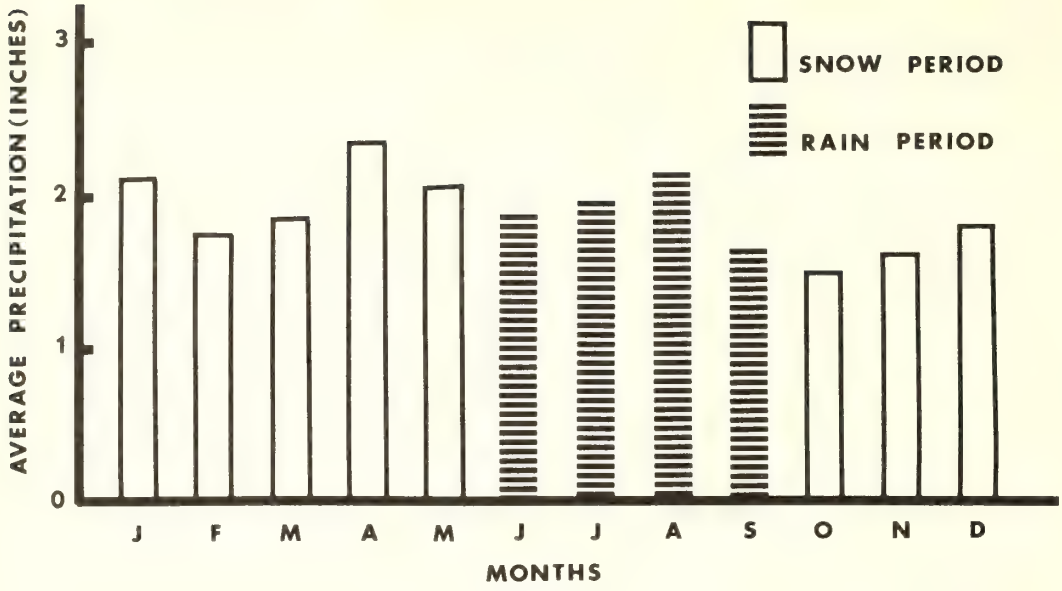
THE FOREST

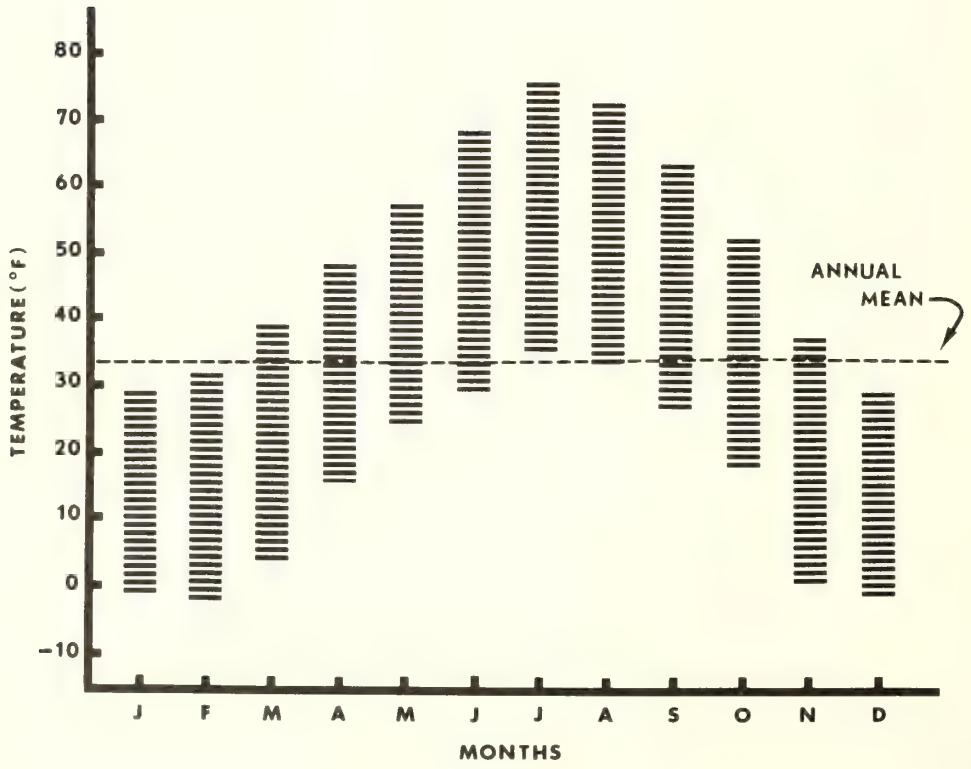
Elevation of the Experimental Forest ranges from 8,800 feet at the main entrance along the road from the town of Fraser, to 12,804 feet at the summit of Byers Peak. About three-fourths of the Forest lies above 10,000 feet, and about one-third is above timberline.



Climate

Climate is cool and humid with long, cold winters and short, cool summers. Average yearly temperature at Forest headquarters (9,000 feet elevation) is 33°F., and frost can occur any month of the year. Mean monthly temperature for January is 14°F, for July 55°F, with an observed range of about -40°F to 90°F. Annual precipitation measured at the headquarters area varies from about 17 to 28 inches, with an average of nearly 23 inches. Precipitation over the entire Experimental Forest averages about 28 to 30 inches with nearly two-thirds falling as snow from October through May.


AVERAGE PRECIPITATION (INCHES)
3
2
1
0
SNOW PERIOD
RAIN PERIOD
J F M A M J J A S O N D
MONTHS

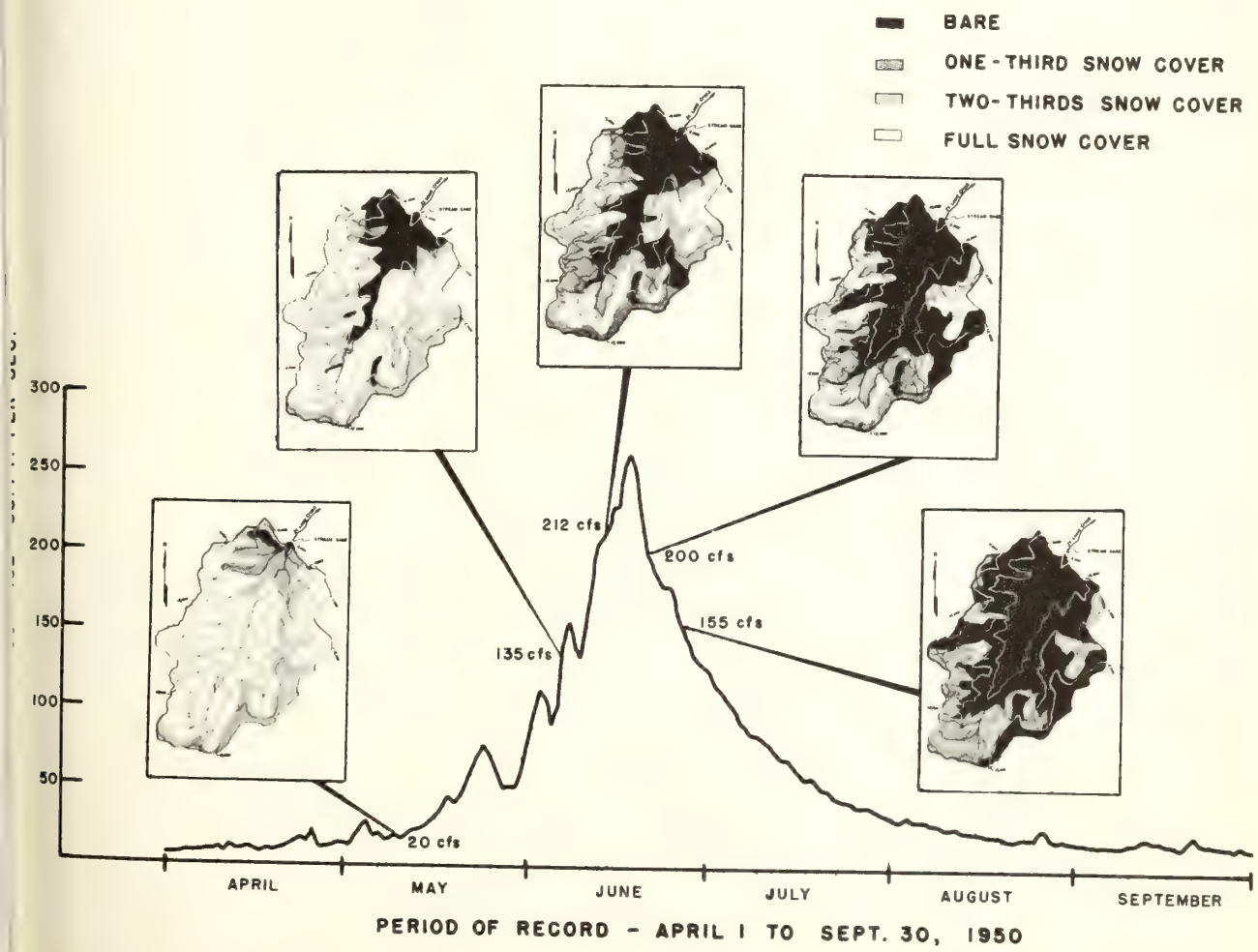

TEMPERATURE (°F)
80
70
60
50
40
30
20
10
0
-10
ANNUAL MEAN
J F M A M J J A S O N D
MONTHS

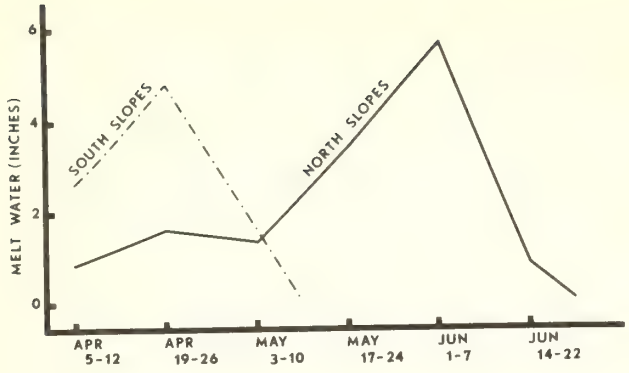
Water Yield

Snowfall is the key to water yield. On the Experimental Forest, the first snow is deposited in late fall, and the pack gradually accumulates to its maximum depth in early spring. Long, cold winters keep temperatures within the snowpack well below freezing until late March or April. Peak seasonal snow accumulation averages about 15 inches water equivalent, and during melt season, the depleting snowpack is augmented by 5 inches or more of additional precipitation. Rainfall during summer and early fall averages 8 to 10 inches. Of the total 28 to 30 inch input, about 12 to 15 inches becomes streamflow. Streams begin to rise from minimum flows in April, reaching peak levels in June. Streamflow then rapidly recedes, nearing baseline flows again in late summer.

Snow Cover Disappearance

The entire Forest is covered with snow by the end of winter. As spring advances, snow disappears progressively from lower to higher elevations. Snow melts and disappears from south slopes first. When 50% of the snow has disappeared, spring streamflow peaks on the main drainage; when 80% of the snow is gone, streamflow is declining. Temperature, humidity, and wind also influence the daily rate of snowmelt which, in turn, governs streamflow. Continuous records of these factors have been useful in calculating rates of streamflow on the St. Louis Creek drainage, and in forecasting daily streamflow.





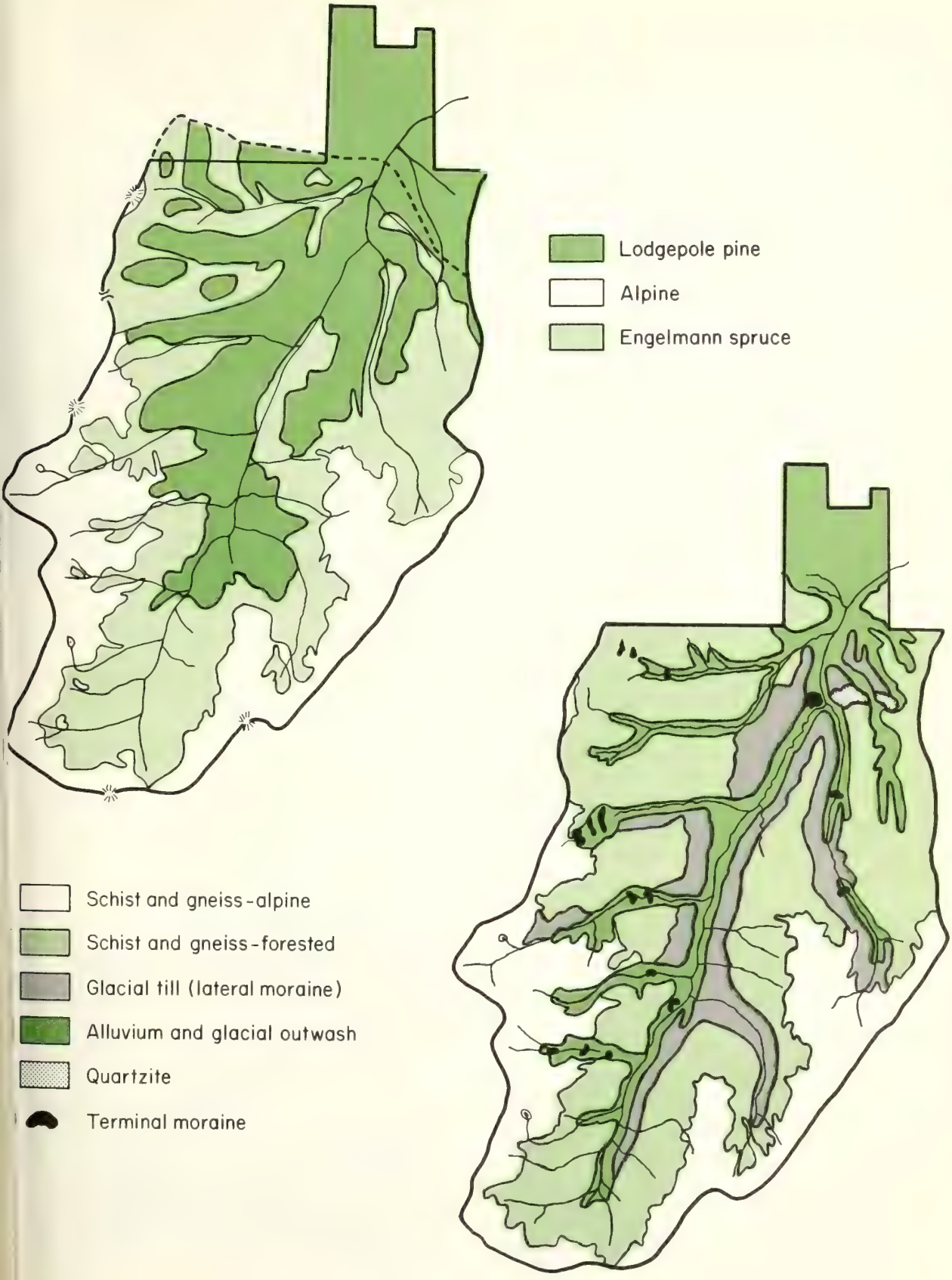
Geology, Landforms and Soils

Topography of the Experimental Forest is typical of the Southern Rocky Mountain Province. The west side of the Forest is characterized by rugged mountains and narrow, steep-sided valleys filled with alluvium and glacial outwash. South and east sides of the Forest are remnants of an old peneplain, dissected by mountain glaciers and characterized by long, gentle, relatively uniform slopes. The north side is a nearly level, broad valley dissected by St. Louis Creek and surrounded by rolling hills.

Parent material of soils on the Forest generally is derived from gneiss and schist rocks. Occasionally, there are small outcroppings of granitic rock, which weathers more slowly than schists. Typical soils from schistic and granitic rock contain angular gravel and stone, with very little silt and clay. They are very permeable and capable of storing considerable amounts of water during snowmelt. At high elevations, especially on the west side of the Forest, soils have developed in material weathered from sandstones. These soils are shallow, have large amounts of stone, and have fine sand or sand textures. Alluvial soils occur along main streams, with parent material a mixture of glacial till, glacial outwash and recent valley fill. Bogs originating from seeps or springs that emerge on slopes are scattered throughout the Forest.

Vegetation

Native vegetation is typical of the subalpin forest zone of the central Rocky Mountains Engelmann spruce and subalpine fir are pre dominant trees at higher elevations, on nort slopes, and along streams; lodgepole pine is th predominant tree at lower elevations and o drier upper slopes. In virgin stands, trees rang from 200 to 400 years old. Second-growt lodgepole pine on the north end of the Fore originated after fires, and is about 60 years ol Scattered patches of aspen occur in areas opene up by logging or fire. Occasionally, a large, ol (450 to 500 years) Douglas-fir can be found. Th forest floor generally is covered with a layer duff and litter and often a dense mat of whortl berry. Little herbaceous vegetation is prese except along streams, and in openings resultin from disturbance. Barren rocks intermix wi alpine tundra, meadows and bogs above timbe line.


Lodgepole pine
Alpine
Engelmann spruce
Schist and gneiss-alpine
Schist and gneiss-forested
Glacial till (lateral moraine)
Alluvium and glacial outwash
Quartzite
Terminal moraine



Wildlife

Many kinds of wildlife live on the Forest, but no one species is abundant. Trout occur in some streams, beaver ponds, and lakes. Elk, deer, black bear, and mountain lion are the Forest's big game animals. Elk are found in alpine grasslands and high cirque basins in summer, but do not winter in any part of the Forest. Mule deer are more common than elk. In summer, they graze in timbered areas and openings intermixed with timber. In winter, they move to lower areas off the Forest. Black bears are shy and rarely seen. Mountain lions are only occasional visitors. Small, fur-bearing mammals include marten, weasel, mink, badger, muskrat, r fox, coyote, bobcat, and beaver along so watercourses. Snowshoe hares, pine squirre porcupines, marmots, chipmunks, grou squirrels, mice, gophers, shrews, and voles a are present. Numerous game and nongame bir occur on the Forest. Some are residents, oth are seasonal, and still others are migratory.

Recreation

The Forest provides a variety of recreatio opportunities, with two developed can grounds, 20 miles of specified roads, and ma





rails. In summer, users camp, hike, fish, back-ack, and view and photograph scenery. In fall, unters seek blue grouse, elk, and deer. Snow-nobiling and ski-touring are popular in winter.



RESEARCH PROGRAM

The research program at the Fraser Experi-ental Forest is concerned with regenerating ew forest stands, increasing growth and yield f trees, increasing water supplies and maintain-g water quality, improving wildlife habitat for ame and nongame animals, and determining e integrated effects of timber harvesting on ese resources. Specifically, research objectives e:

1. Understanding how trees grow, reproduce and interact; how the hydrologic system operates on headwater streams, and what the food and cover requirements of wildlife are.
2. Learning how natural forest cover influences the tree, water and wildlife systems.
3. Observing how management through harvesting timber changes the influence of the forest on these systems; and
4. Devising timber harvesting systems to achieve the desired changes in forest cover that will provide the best mix of timber, water and wildlife benefits.

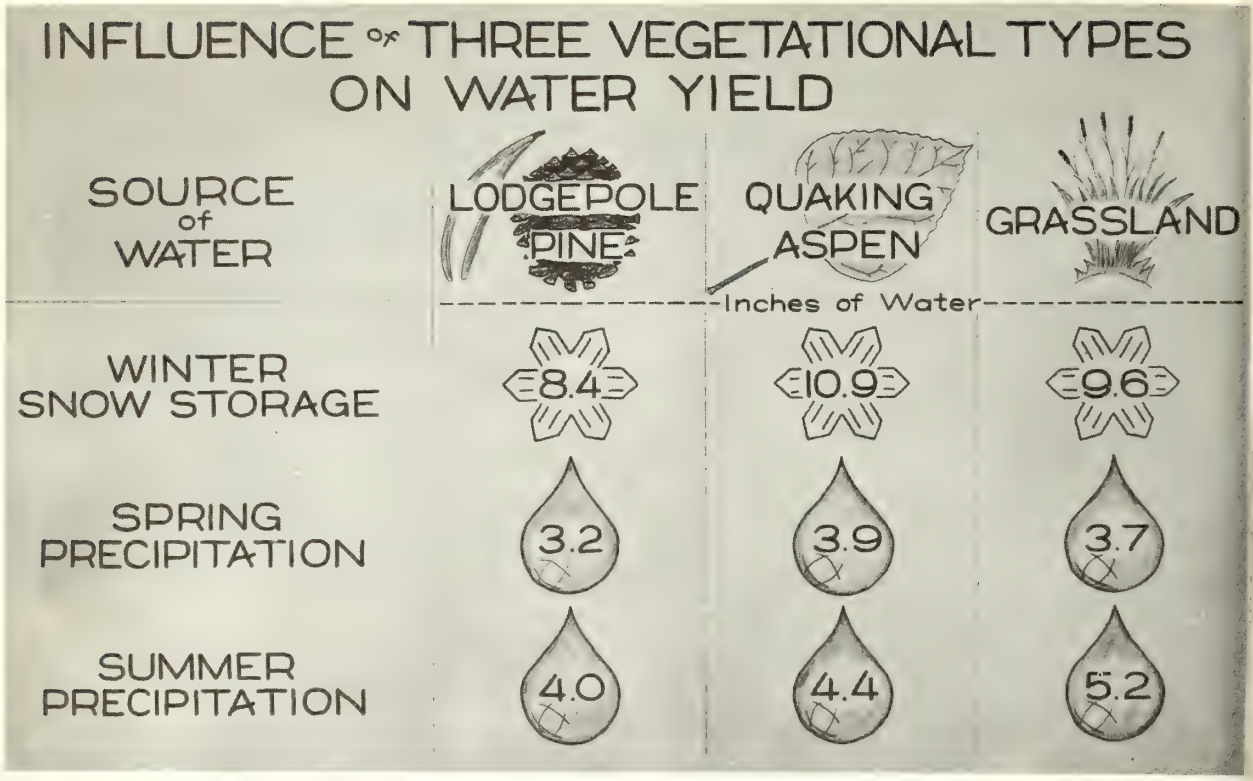
RESEARCH HIGHLIGHTS

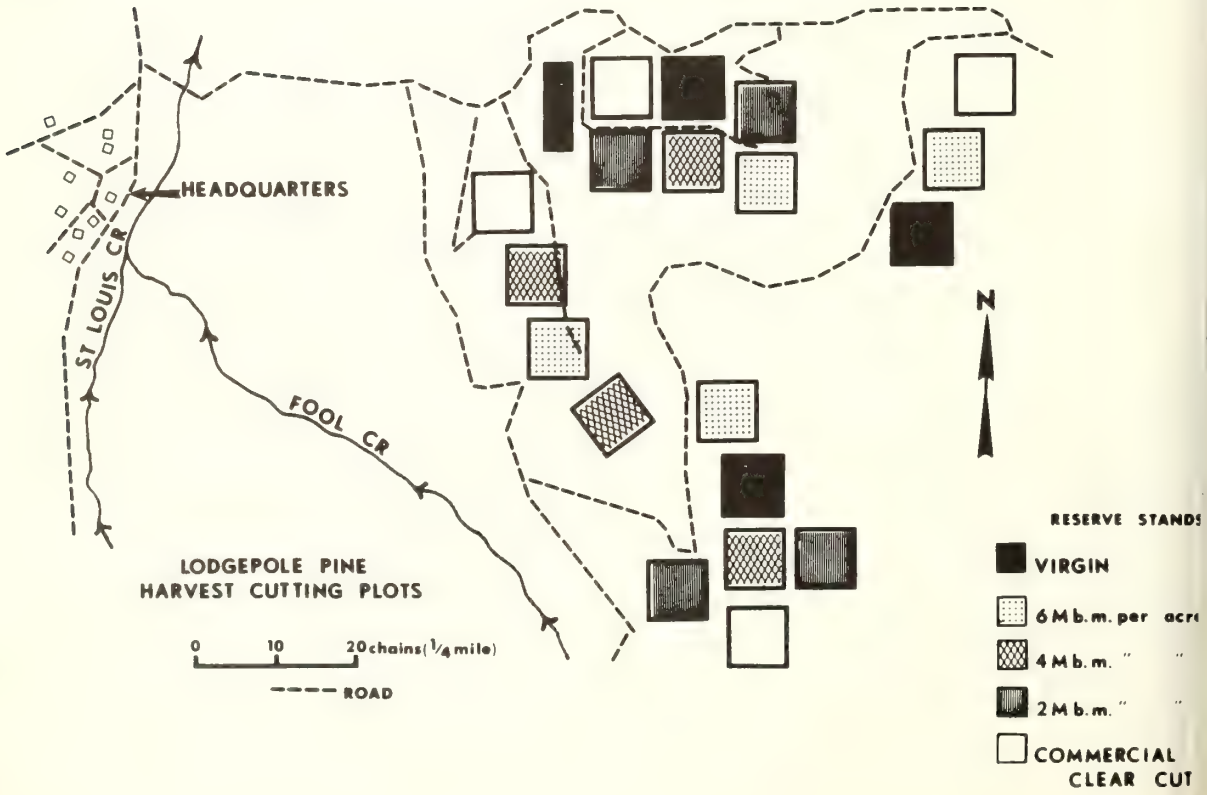
Early studies included observations in natural plant communities or environments to determine their effects on snow accumulation. Results showed more precipitation reached the ground under aspen and in grasslands, than under dense lodgepole pine stands. These studies provided clues to the effect on water yield when forest stands were harvested for timber or thinned to improve growth.

Plot studies of harvest cuttings and thinnings followed. Their purpose was to determine how different methods and intensities of tree removal affected the snowpack and tree reproduction, growth, and mortality. A third research phase applied a timber harvesting system to an entire watershed to measure its effects on (1) streamflow and snow accumulation and melt; (2) sedimentation; (3) tree regeneration and mortality; and (4) big game use, forage availability and preference. This included basic hydrologic studies aimed at measuring water loss from both vegetation and the overwinter snowpack. The present phase involves pilot testing of timber, water, and wildlife systems and their interactions in relation to timber harvesting on other watersheds.

Harvest Cutting in Lodgepole Pine

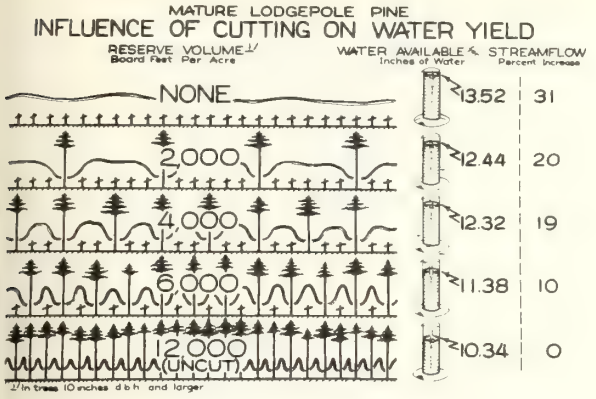
Twenty 5-acre plots were established in 1938 on the King Creek drainage in mature lodgepole pine. After snowpack, regeneration, and stand inventory measurements, plots were logged in 1940, with treatments ranging from clearcutting to no cutting. Residual volumes in trees 9.5 inches in diameter and larger on logged plots were 0, 2,000, 4,000, and 6,000 board feet (fbm) per acre. Uncut plots averaged about 12,000 fbm per acre.


INFLUENCE of THREE VEGETATIONAL TYPES ON WATER YIELD
SOURCE of WATER
LODGEPOLE PINE
QUAKING ASPEN
GRASSLAND
Inches of Water
WINTER SNOW STORAGE
8.4
10.9
9.6
SPRING PRECIPITATION
3.2
3.9
3.7
SUMMER PRECIPITATION
4.0
4.4
5.2


HEADQUARTERS
ST LOUIS CR
FOOL CR
LODGEPOLE PINE
HARVEST CUTTING PLOTS
0 10 20 chains (1/4 mile)
ROAD
N
RESERVE STANDS
VIRGIN
6 M b.m. per acre
4 M b.m. "
2 M b.m. "
COMMERCIAL CLEAR CUT

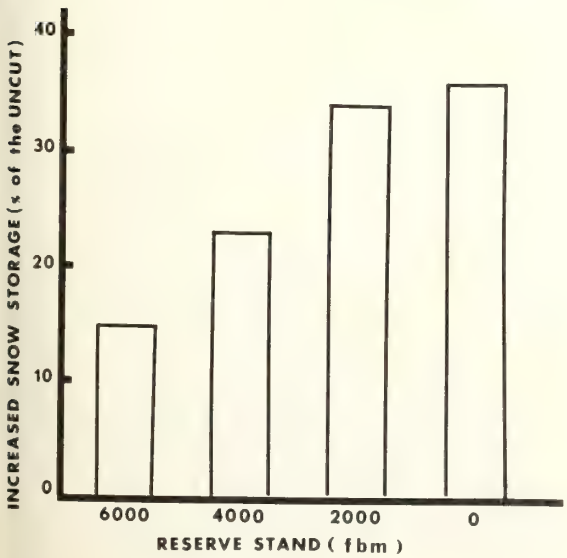
Water Available for Streamflow

Harvesting trees resulted in more water available for streamflow. The largest increase was on clearcut plots, the smallest was on 6,000 fbm reserve plots.



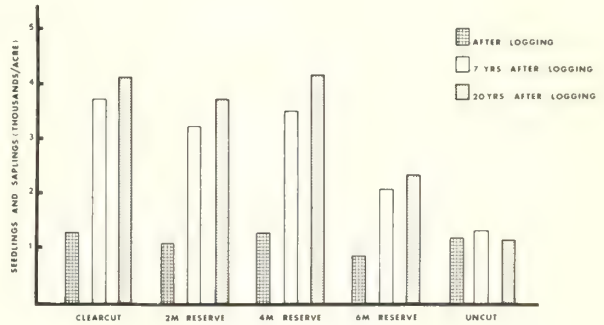
Snow Accumulation

Most of the increase in water available for streamflow came from increased snow storage on cutover plots. Although young trees developed rapidly on cutover plots, snow storage amounts have changed little in the years since cutting. This indicates the major cause of increased snow on cutover plots is the aerodynamic effect on snow distribution rather than reduced interception loss. Wind transports snow intercepted by trees in the surrounding uncut forest and deposits it in openings created by cutting trees. This pattern will persist until new trees, established after logging, are tall enough to change the aerodynamic effect on snow accumulation. To increase snow accumulation, clearcutting of mature lodgepole pine in small patches is the most desirable method of harvesting.



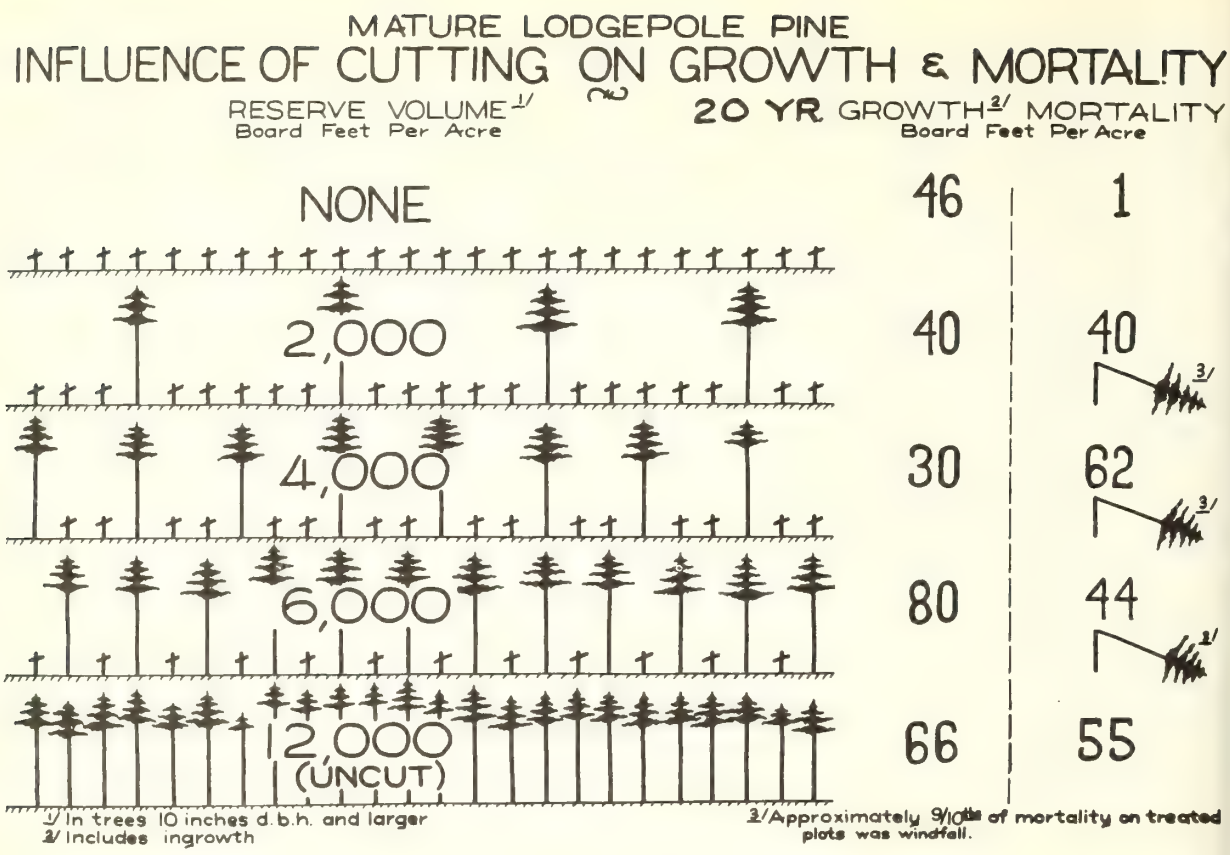
Regeneration

Enough new trees were established on all cutover plots. Before cutting, plots contained 1,978 seedlings and saplings per acre. Logging, where skidding was done with horses, destroyed 44% of the advanced growth, but new seedlings came in rapidly after logging. In only 7 years, new seedlings increased total reproduction twofold to threefold on all cutover plots. The increase was greatest on clearcut plots and least on 6,000 fbm reserve plots. Reproduction continued after 1947, but at a much slower rate, and the increase was not directly related to cutting method.



Growth and Mortality

Heavy mortality during the first 7 years after cutting resulted in little new growth on 6,000 fbm reserve and uncut plots, and an actual loss of volume on 2,000 and 4,000 fbm reserve plots. No measurable mortality occurred on clearcut



plots because no merchantable-sized trees were left. After 1947, mortality declined, and net growth increased on all plots. After 20 years, however, only the 6,000 fbm reserve plots grew more than uncut plots. Windfall was responsible for nearly all mortality on partially cut plots and about half the mortality on uncut plots. Because of heavy mortality, clearcutting and replacement of the old stand with a vigorous new one is recommended as the most desirable method for harvesting old-growth lodgepole pine. Partial cutting requires leaving large reserve volumes of low vigor trees, increasing the risk of future mortality.

Harvest Cutting Spruce-Fir

In 1944, four 8-acre plots were established on the West St. Louis Creek drainage to evaluate methods of cutting in old-growth spruce-fir for ests. Treatments tested were alternate-stri clearcutting, group selection cutting and indivi dual tree selection cutting. Each treatment re moved 60% of the volume in trees 9.5 inche diameter at breast height (d.b.h.) and larger. Al ternate-strip clearcutting removed 50% of th volume in alternate strips 1 chain wide; an add tional 10% was removed from the leave strip by cutting overmature trees. Group selectio cutting was used to remove 50% of the volum in small circular openings about 1 chain i diameter; an additional 10% was removed b cutting trees in the between-group stand. Indiv dual tree selection cutting removed 60% of th volume uniformly over the entire plot. Residu volumes on cutover plots averaged 6,460 fb per acre. The original volume of 17,745 fbm p acre remained on the uncut plot.





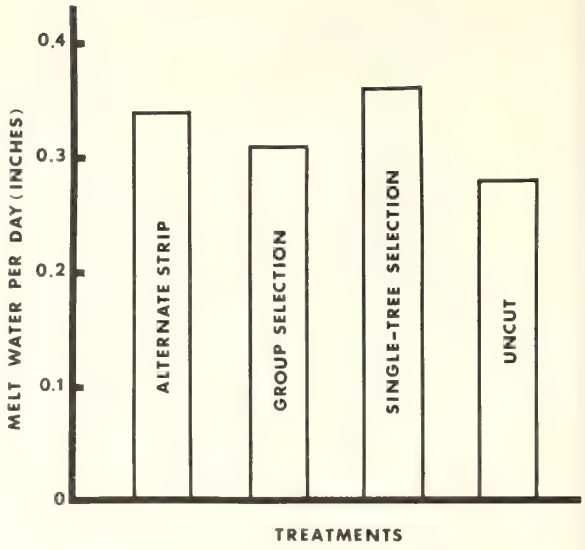


Snow Accumulation

Snowfall reaching the ground increased on all cutover plots after logging. Measurements in four of the years after logging showed an average accumulation of 22% more water equivalent on cutover plots than on the uncut plot, but there were no differences in snow storage between treatments.

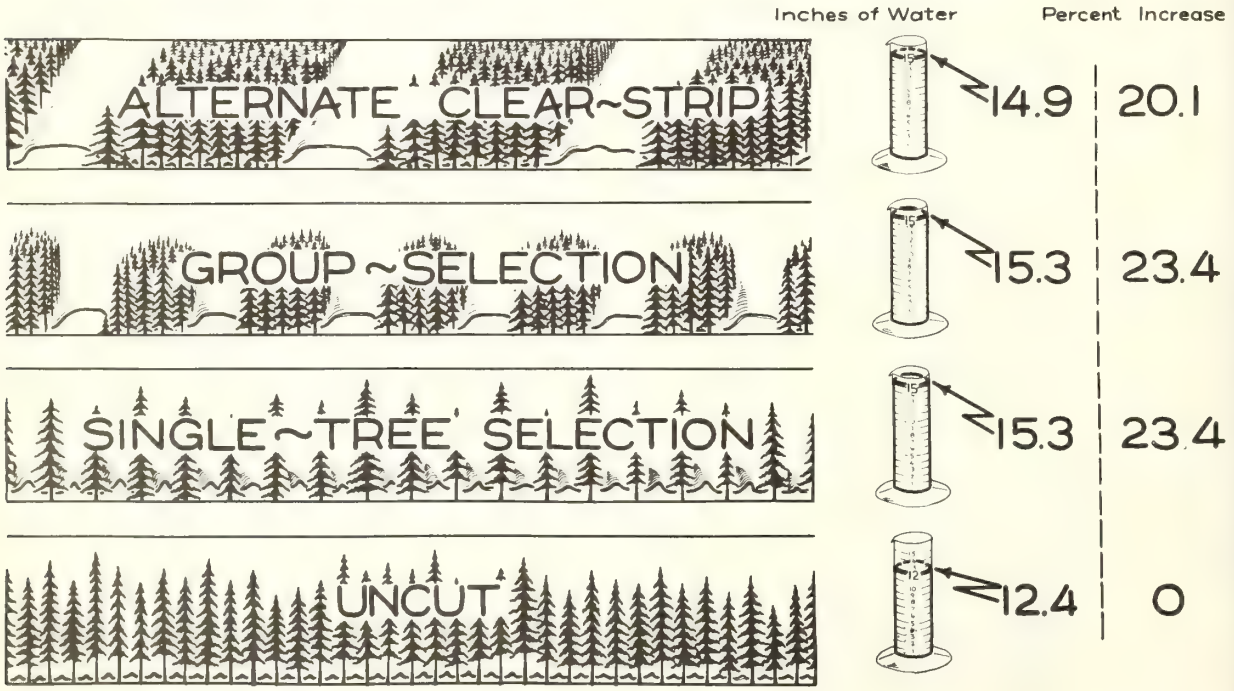
Snowmelt

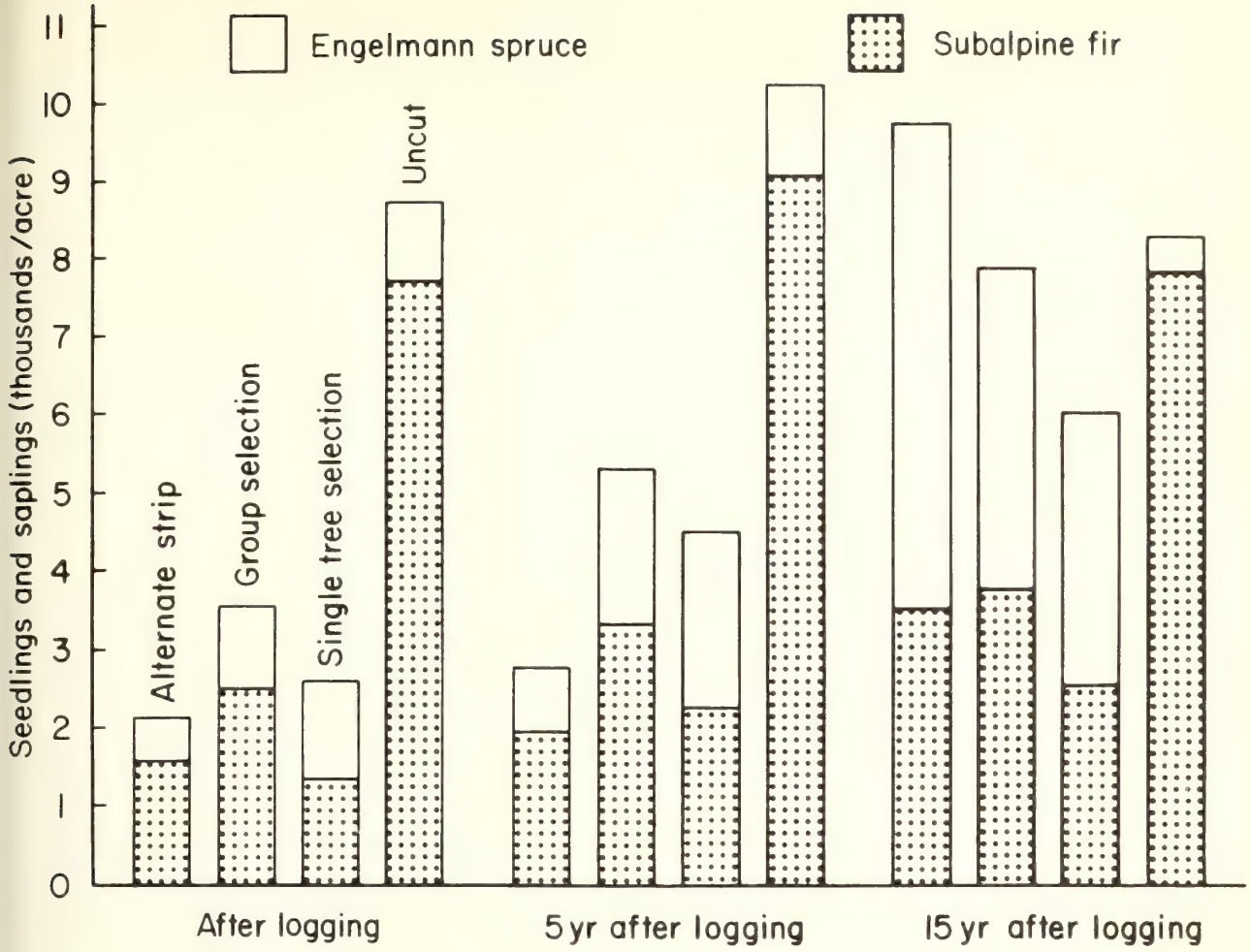
Weekly measurements of rates of snowmelt during the spring showed only slight differences between treatments. Snow melted fastest (0.36 inch per day) after individual tree selection cutting and slowest (0.28 inch per day) in the uncut plot.



OLD~GROWTH SPRUCE~FIR

INFLUENCE OF HARVESTING METHODS ON SNOW STORAGE



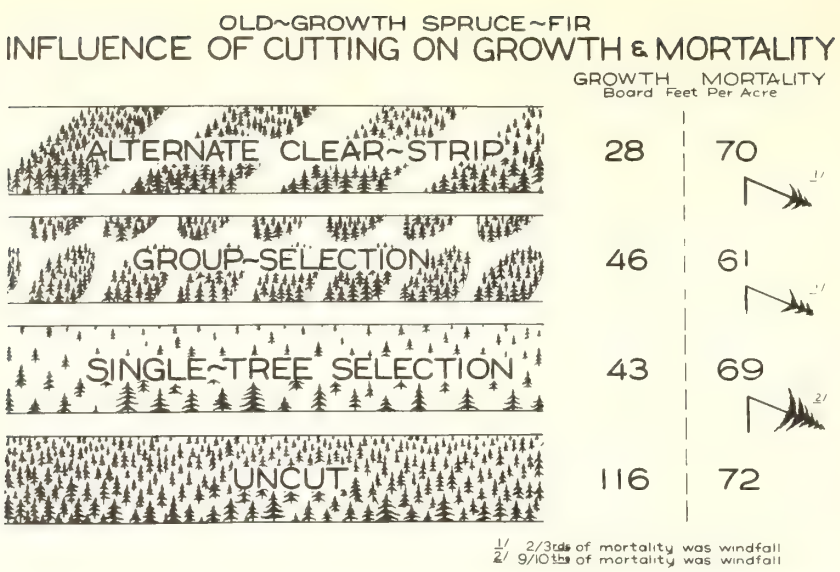


Regeneration

Reproduction was adequate under any cutting method tested. Before logging, plots averaged 6,344 seedlings and saplings per acre, with the ratio of fir to spruce ranging from 5 to 1 on the alternate strip clearcut plot to about 1 to 1 on the individual tree selection plot. Logging where skidding was with horses, destroyed 52% of the advanced reproduction. Damage among the three cut plots was heaviest on the individual tree selection plot where the entire area was disturbed, and was least on the group selection plot where about one-third of the area was disturbed. Subsequent reproduction established at only a moderate rate during the first 5 years after logging. Initial recovery was poorest on the alternate strip clearcut plot, where only about half as many trees established as on other cutover plots. The rate new reproduction established accelerated after 1949. The largest increase was on the alternate strip clearcut plot where new reproduction outnumbered the increase on group and individual tree selection cutting plots by three and four times, respectively. The number of new spruces was three to five times greater than new firs on all cutover plots.

Growth and Mortality

Growth of residual stands was not stimulated by the cutting methods tested. Furthermore, differences in board foot volume growth between

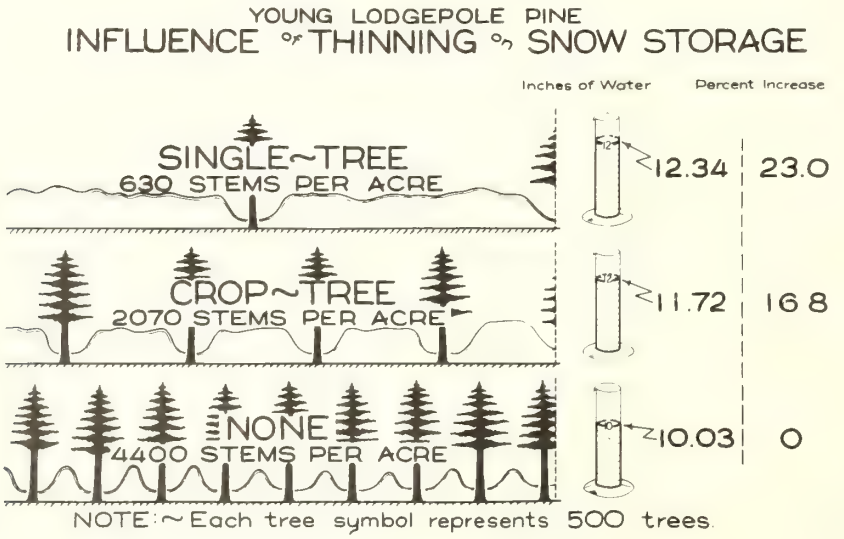


cutting treatments were unimportant. Mean annual growth on all plots was proportional to reserve volume.

Mortality was not materially different between plots. Windfall caused at least two-thirds of the mortality on cutover plots, with the heaviest losses on the individual tree selection plot. Disease and insects were responsible for most of the mortality on the uncut plot. Because of more abundant and better distributed spruce reproduction, and less susceptibility of residual stands to windthrow, alternate strip clearcutting and group selection cutting are the most desirable harvesting method tested for old-growth spruce-fir stands.

Thinning Young Lodgepole Pine

Eighteen ¼-acre plots were established in 1944 in young (35-year-old) lodgepole pine stands on St. Louis Creek to test thinning methods. Original stand density varied from 2,100 to 8,576 stems per acre. After snowpack and stand inventory measurements, six plots—designated single tree—were thinned uniformly from below in 1945, reserving 630 trees per acre. On six other plots — designated crop tree — all trees within a 16-foot diameter circle around each of 100 crop trees per acre were cut. The remaining six plots were left unthinned as a control.

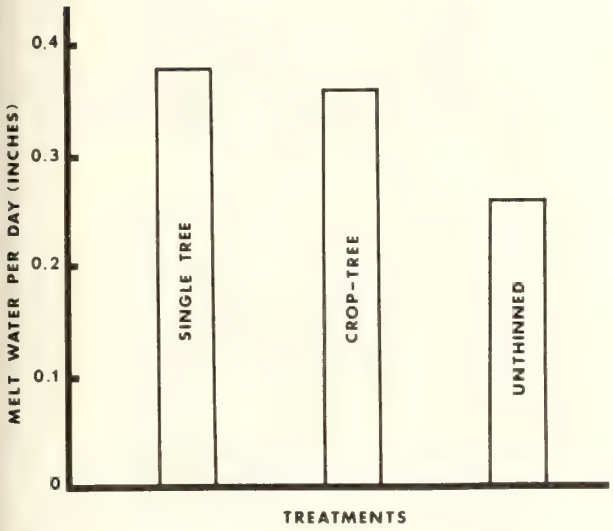


Snow Accumulation

Cutting resulted in more snow reaching the ground on thinned plots than in natural stands. The highest snow accumulation observed during a 3-year period was on single-tree plots where the largest number of trees were removed.

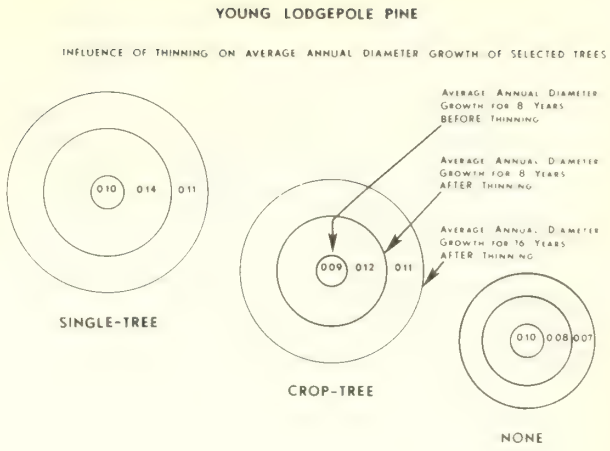
Snowmelt

The rate of snowmelt during spring was greater on thinned than unthinned plots, but there was little difference in melt between single-tree and crop-tree thinning.



Growth

Diameter growth of the best 100 trees per acre was increased about 1½ times by both thinning methods during the 16 years of observation, but diameter growth of all trees on plots was increased only by single-tree thinning. Basal area increment of the total stand was not affected by thinning. Cubic volume growth during the first 8 years of observation was greater in unthinned than thinned stands, but during the last 8 years of observation, there was no difference in cubic volume growth between thinned and unthinned plots.



Because of larger increases in water available for streamflow and concentration of total stand growth on fewer stems, single-tree thinning is recommended.

Watershed Studies—Fool Creek-East St. Louis Creek

Since more snow accumulated on experimental plots after timber harvest, it was assumed that more water was available for streamflow.[2] It was only an assumption, however, until similar cutting was done on a forested watershed where streamflow was measured.

Fool Creek.—This 714-acre watershed at elevations ranging from 9,500 to 11,500 feet, was selected for treatment. Streamflow, rainfall and snow storage have been measured since 1940. The gaging station at Fool Creek is a combination San Dimas flume and two broadcrested weirs. The main channel flows north, with generally east and west aspects comprising 70% of the watershed area.

East St. Louis Creek.—This is a 1,984-acre watershed with elevation varying from 9,500 to 12,200 feet. It lies adjacent to Fool Creek, and is

[2]*Streamflow is the quantity of surface water flowing past a given point in a stream channel. It is measured by flumes, weirs, or water control structures. Streamflow generally is expressed as a rate in cubic feet per second, or as an amount in acre-feet, or inches depth over a known area.*


FOOL CREEK
EAST ST. LOUIS CREEK
Gaging Station



the untreated control. Major vegetation consists of lodgepole pine, Engelmann spruce and subalpine fir, with alpine tundra above timberline. Streamflow and snow storage have been measured since 1943. The original gaging station at East St. Louis Creek was a trapezoidal flume that was replaced in 1963 with a Cipolletti weir. Flow from the two watersheds correlates well, and changes in streamflow on Fool Creek resulting from timber harvest are estimated from the flow of East St. Louis Creek.

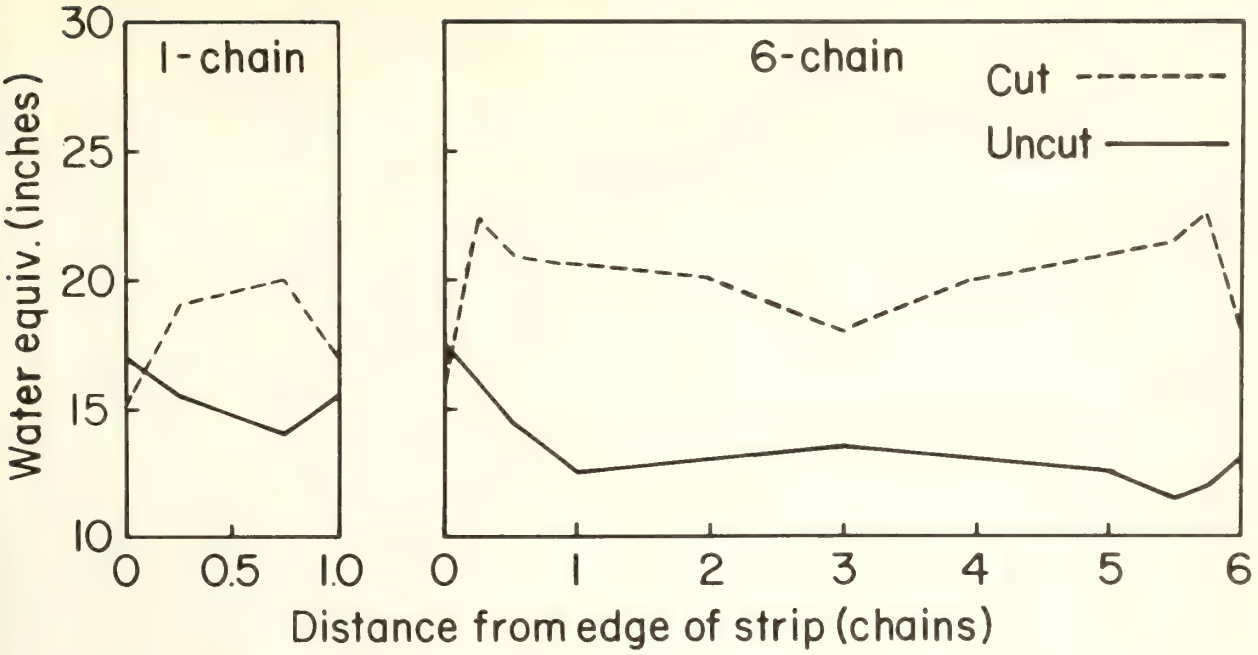


Alternate Strip Clearcutting

Fool Creek originally supported 6 million fbm of merchantable timber on 550 acres. About 55% was in the lodgepole pine type and 45 percent in the spruce-fir type. These stands were overmature, 250 to 350 years old. To harvest timber on Fool Creek, 3.3 miles of main access road and 8.8 miles of spur roads were constructed between 1950 and 1952. Spur roads were about 600 feet apart, located on the contour. Timber harvest, beginning in 1954 and ending in 1956, removed trees in alternate cleared strips at right angles to the contour. Four widths of clearing—1-, 2-, 3-, and 6-chains wide—were used. No timber was cut within 90 feet of the stream to minimize damage to the channel. On strips designated for cutting, all live trees 4 inches in diameter and larger were felled, and tops were lopped and scattered. In all, 278 acres of watershed were cleared, including 35 acres of roads. A total of 3.5 million fbm of timber was removed.





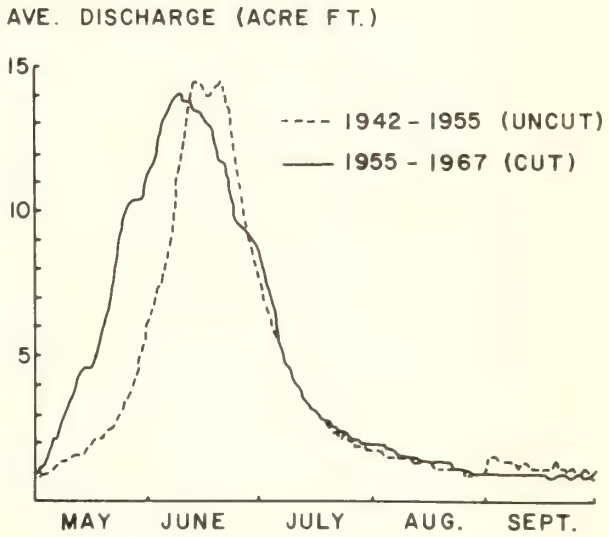


Snow Accumulation

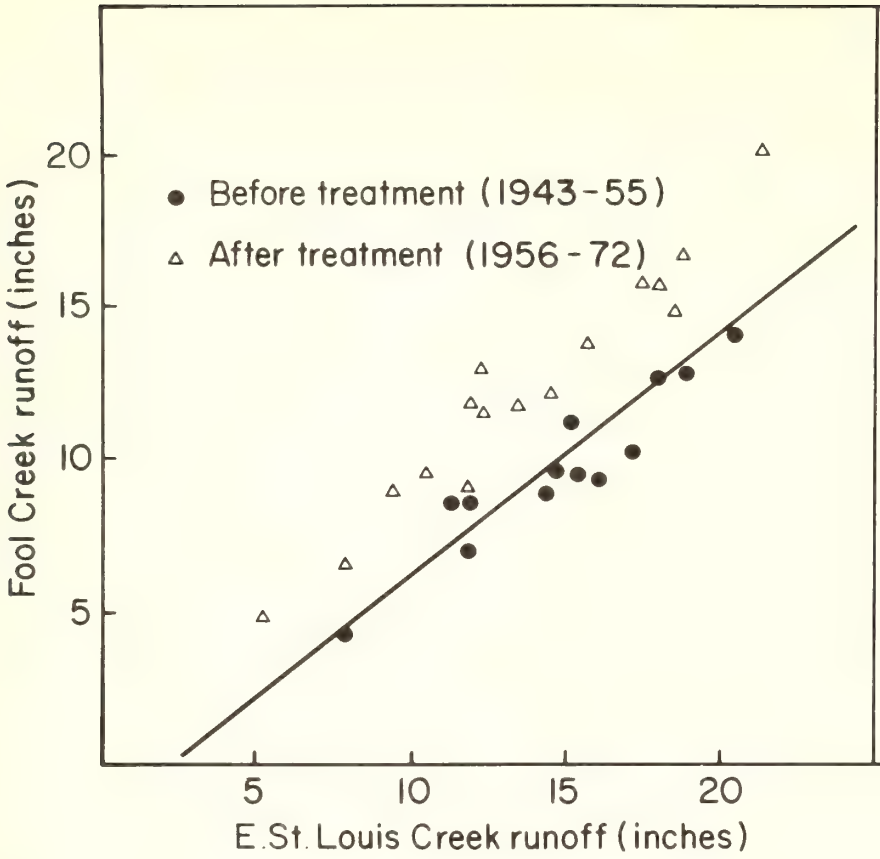
Comparisons of snowpack in alternate forested and clearcut strips show more water equivalent in open areas but no increase in total snow storage on the watershed. There is, however, a pronounced redistribution of snow as a result of cutting; more snow accumulates in cut strips than in the uncut forest. Before cutting, wind distributed snow rather evenly within the forest. Afterwards, openings increase wind stress on the remaining forest canopy and efficiently trap snow that formerly settled in adjacent forested strips.

Snowmelt and Water Yield

Removing timber from Fool Creek accelerated snowmelt rates and increased water yield by more than 25%. Most of the increase is due to a substantially enlarged spring runoff. Peak flows are not affected appreciably, and there is little change in streamflow during late summer and early fall despite higher snowmelt rates and more efficient water yield in early spring. More than 20 years have passed without any strong indication that the effect of cutting timber on streamflow has diminished.



Cutting trees and resultant redistribution of seasonal snowpack substantially increased runoff because some water formerly used to replace soil moisture consumed by vegetation is now available for streamflow, and more snow is deposited in openings where soil moisture deficits are lowest. Higher melt rates in openings further reduce water losses from evapotranspiration.



April - Sept. Runoff Increase Since Harvest

Year	Inches
1956	3.3
1957	5.2
1958	3.7
1959	4.6
1960	5.4
1961	3.4
1962	3.9
1963	2.9
1964	3.5
1965	4.0
1966	2.6
1967	3.1
1968	1.9
1969	2.5
1970	2.1
1971	3.6
1972	3.9
Mean	3.5 ±0.8*

*95 Percent level of confidence

Sediment Yields

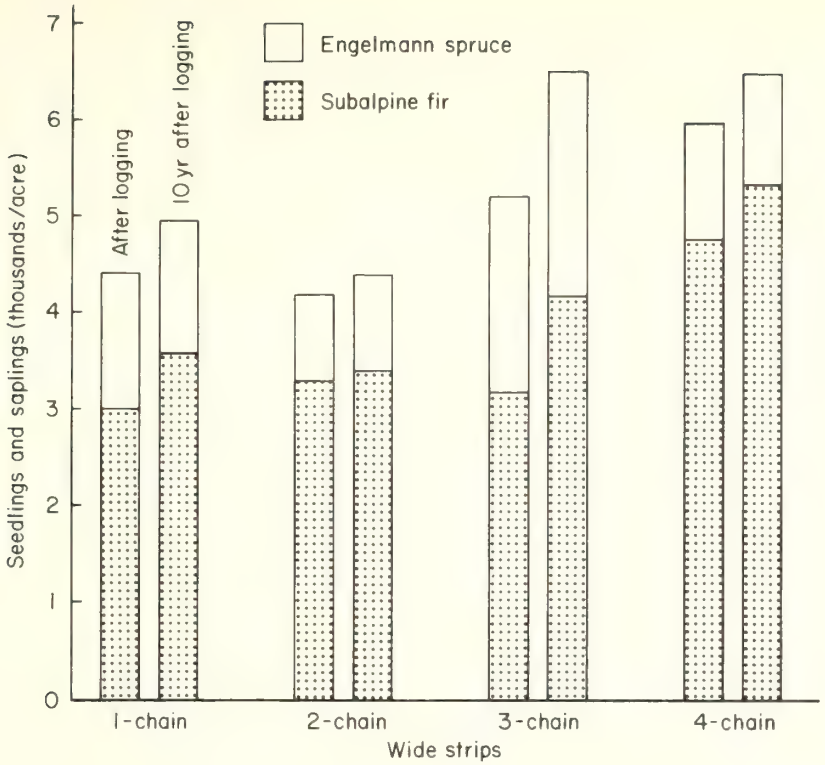
Construction of the road system on Fool Creek and associated timber harvesting caused little erosion, with no apparent reduction in water quality. The main access road was located to avoid damage to the stream channel, and spur roads were provided with surface drainage and culverts at stream crossings. After logging, spurs were seeded to grass, and culverts were removed from alternate spur roads to reduce traffic. The main haul road is still routinely maintained.

Sediment yield during road construction and logging averaged about 200 pounds per acre, but decreased rapidly after logging despite continuing increase in runoff after timber harvest. Since logging, sediment yields have averaged 43 pounds per acre, compared with yields of 11 to 21 pounds per acre from undisturbed watersheds. Suspended sediment was less than five parts per million during high flow periods in 1964 and 1965.



Regeneration: Spruce-Fir Type

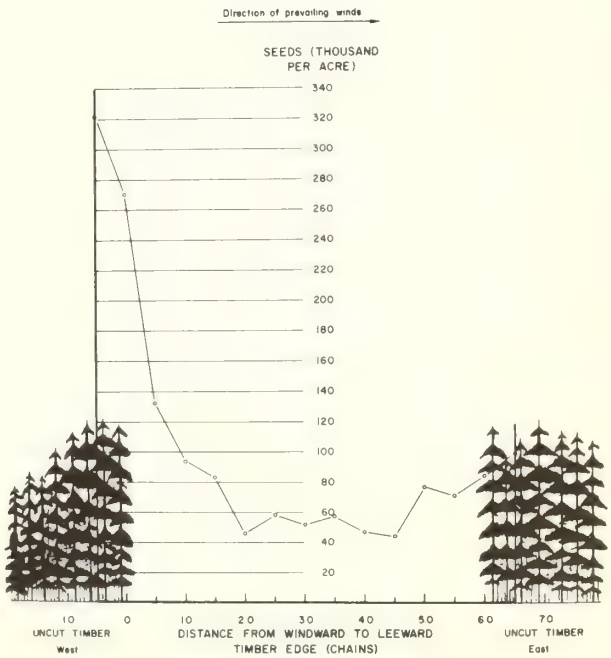
In the spruce-fir type on Fool Creek where logs were skidded with horses, enough advanced reproduction survived logging to restock all cutover strips. Numbers of seedlings and saplings



left after logging ranged from 4,183 per acre on 2-chain-wide strips to 5,957 per acre on 6-chain-wide strips. Firs outnumbered the more valuable spruces on all strip widths. Subsequent reproduction was not abundant on any strips 10 years after cutting. Recovery was best on 3-chain-wide strips, and poorest on 2-chain-wide strips. More new firs than spruces were established on all but 2-chain-wide strips.

Seed Dispersal: Engelmann Spruce

An adequate supply of viable seed is necessary for natural reproduction. During a 10-year period, 1956 through 1965, Engelmann spruce seed production in uncut strips on Fool Creek was 321,000 sound seeds per acre, but annual seedfall varied considerably. The 1961 crop contributed about 40 % of the total seedfall. Moderate crops were produced in 1959 and 1963, but seed crops were rated poor to complete failure in the other seven years of observation. Number of seeds dispersed from standing trees into the cleared strips was greater in years of heaviest seed production, but seedfall was not uniformly distributed over the openings. In the 6-chain-wide strips, about half the seed dispersed fell within 1.5 chains of timber edge, with only about 10% falling near the center of the openings.



Windfall

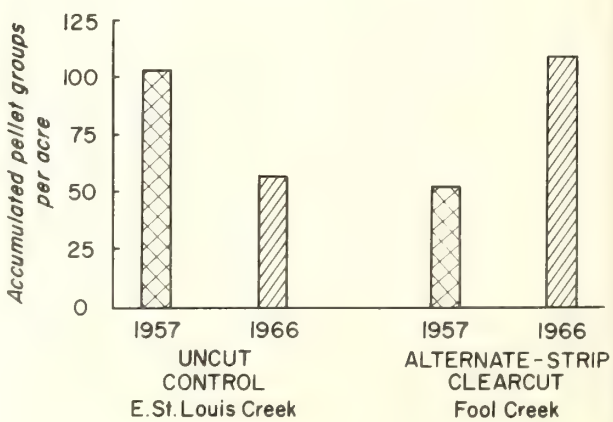
Windfall after clearcutting on Fool Creek was observed for 10 years after cutting was completed. Blowdown was related to exposure to wind, cutting unit characteristics, and tree characteristics in the following ways:

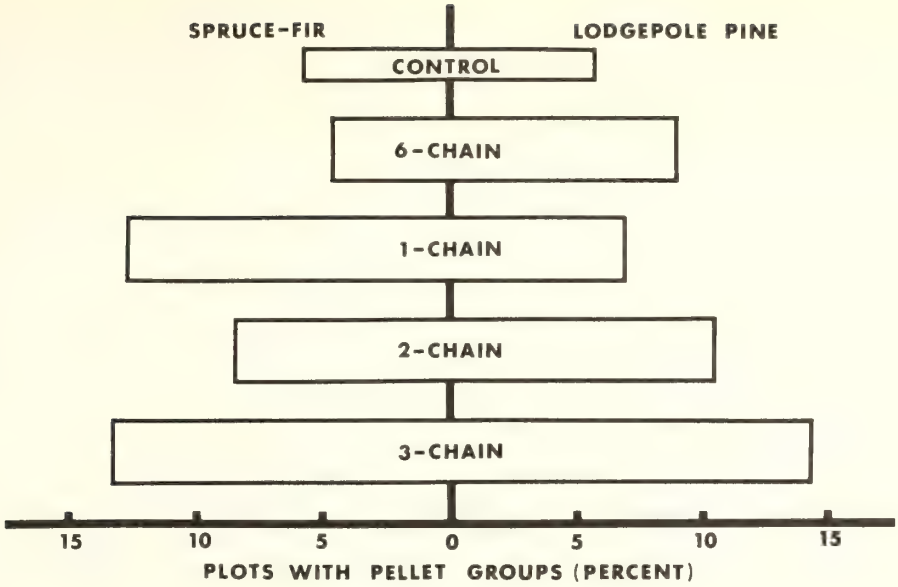


1. Approximately 70% of 2,844 windthrown trees were felled by stormwinds from the west and the southwest.
2. About two-thirds of the trees blew down along the N, NE, E, and SE (leeward) cutting boundaries.
3. More trees were windthrown on downwind than on upwind aspects.
4. Cutting boundaries on ridgetops suffered heavy damage. Fewer and about equal numbers of trees blew down on upper, middle and lower slopes.
5. Windfall was not directly related to width of opening.
6. Cutting boundaries oriented parallel to the direction of prevailing windstorms suffered more damage than those oriented at right angles to windstorms.
7. About two-thirds of the blowdown occurred within the first 2 years after logging.
8. Trees growing on soils where average depth of solum exceeded 12 inches were more windfirm than trees growing on shallower soils.
9. Trees growing in situations with rapid drainage were more windfirm than trees growing where drainage was slow.
10. All species and size classes were predisposed to windthrow in the same proportion in which they occurred in uncut stands.
11. Defect was associated with one third or less of windthrow trees.

Mule Deer Use and Forage Values

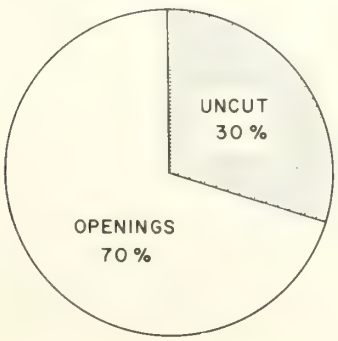
Immediately after logging, mule deer summer use on Fool Creek was less than on the adjacent unlogged watershed. Comparatively low use on Fool Creek may have been due to logging slash, and other disturbance associated with timber harvest. Ten years after logging, deer use was substantially higher on Fool Creek than on the control watershed, with most of the increase on cut strips. Comparisons among cut strips indicated 3-chain-wide strips were used most heavily on both spruce-fir and lodgepole pine forests. The 1-chain-wide strips were used least in lodgepole pine, while 6-chain-wide strips were used least in spruce-fir.





Tame mule deer observed in food habitat studies spent about 70% of their time and obtained about 70% of their food on cut strips. Since there were no differences between cut and uncut areas with respect to digestibility, crude protein content, or moisture content of forage species, deer preference for open areas was associated with increased amounts and variety of forage in cut strips. Although logging stimulated habitat changes beneficial to deer, enough forage was produced in unlogged areas to carry more deer than currently occupy the summer range. Deer populations in this area are limited by availability of winter range at elevations lower than on the Forest.

DEER USE OF OPENINGS AND UNCUT TIMBER



CURRENT RESEARCH

Watershed Studies: Deadhorse Creek—Lexen Creek

The hydrology of Deadhorse and Lexen Creeks has been studied since 1955. Long records of streamflow, snow accumulation and depletion, precipitation, sediment yield and water quality are available. A comprehensive study of the snowmelt regime on these and other watersheds on the Fraser Experimental Forest resulted in development of a simulation model capable of predicting short- and long-term hydrologic impacts of a broad range of land-use alternatives. The system represents the state of the art after more than 30 years of watershed management research in subalpine coniferous forests. Any tool of this complexity and scope requires pilot testing before routine operational application. Pilot testing will be accomplished on Deadhorse Creek by (1) simulating several timber harvesting options on various subunits, (2) selecting and applying one of these alternatives on the ground in each subunit, and comparing the runoff response predicted by the model with actual streamflow.

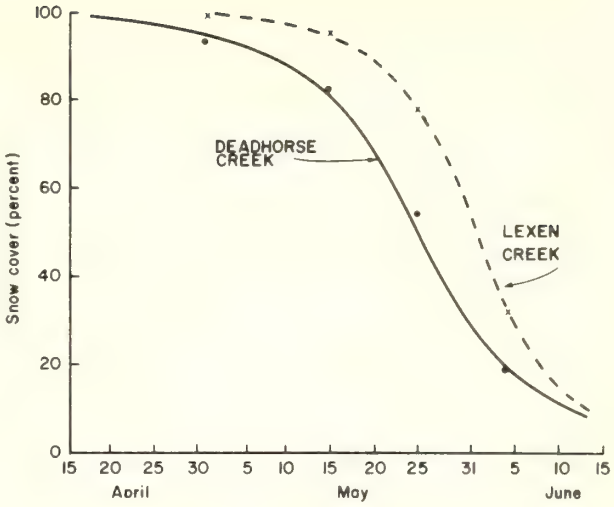


Deadhorse Creek.—This 667-acre watershed that generally drains from west to east, has been selected for treatment. Elevations vary from 9,450 feet at the main gaging station to 11,600 feet at the summit of Bottle Mountain. Major vegetation is spruce-fir along stream bottoms and all north and upper slopes, lodgepole pine on all lower and mid-south slopes, and alpine tundra above timberline. Deadhorse Creek is steeper than Fool Creek, with side slopes averaging almost 40%. The north and south exposures receive unequal amounts of heat in contrast to nearly equal radiant energy load on the east and west slopes of Fool Creek. The three stream gaging stations on Deadhorse Creek—on the main stream, on the 100-acre North Fork and on 200-acre Upper Basin—are 120° V-notch weirs. The main stream gage was constructed in 1955, the North Fork in 1970, and the Upper Basin in 1975.



Lexen Creek.—This is a 306-acre watershed at elevations ranging from 9,850 feet at the stream gaging station to 11,600 feet. It lies adjacent to Deadhorse Creek and will be the untreated control. Vegetation, soils, and topography are similar to Deadhorse Creek. The stream gaging station is a 120° V-notch weir constructed in 1955. Flows from the two watersheds are well-correlated, and Lexen Creek also can be used to estimate changes in streamflow on Deadhorse Creek caused by timber harvesting.





Pretreatment Hydrology

Snow Cover Depletion.—Aerial depletion of the snowpack on Deadhorse Creek starts earlier than on Lexen Creek because of advanced snowmelt on the low-elevation south slopes. The rate of depletion on the Upper Basin of Deadhorse Creek is similar to Lexen Creek.

Snowmelt.—Snowpack melt rates differ considerably between low elevation north and south slopes on Deadhorse Creek. Time of maximum snowmelt on the Upper Basin of Deadhorse Creek and on Lexen Creek varies considerably less between north and south slopes. As a result, nearly 90% of seasonal runoff volume is generated before 60% of the area is bare of snow in the Upper Basin of Deadhorse Creek and on Lexen Creek. Also, more than 80% of these areas are covered with snow when seasonal peak snowmelt runoff rates are reached.

Water Yields.—Streamflow from Lexen Creek can vary from 60% of Deadhorse Creek in high runoff years to nearly 90% in low runoff years because of differences in contribution to streamflow from the Upper Basin and lower Deadhorse Creek. The runoff above base flow on lower Deadhorse Creek averages less than 30% of that generated from the Upper Basin, even though precipitation at lower elevations is 80% of that at higher elevations. Low elevation water yields on Deadhorse Creek vary from near zero for poor runoff years to about 50% of the flow generated in the Upper Basin in good runoff years.

Sediment Yields.—Yields averaged 11 to 21 pounds per acre before road building and logging. These watersheds are very stable, characterized by coarse drainage structure and mature topography. Sediment yields are correlated with both peak and annual flows. In the undisturbed state, most total sediment load comes from stream bank erosion and channel degradation. Trapped elements range from well-graded gravel to fine sand.

YEAR	GENERATED RUNOFF[1/]		RATIO OF RUNOFF,
	DEADHORSE CREEK	LEXEN CREEK	LEXEN:DEADHORSE
	- - - ACRE-FEET - - -		- - PERCENT - -
1956	647.8	397.0	61
1957	1,041.9	623.9	60
1958	688.8	424.6	62
1959	533.4	345.8	65
1960	595.2	384.0	64
1961	269.3	233.0	87
1962	943.9	580.0	61
1963	139.7	120.5	86
1964	339.5	275.4	82
1965	628.3	383.0	61
1966	213.3	186.7	88
1967	463.0	329.3	71
1968	439.1	328.9	75
1969	428.0	297.5	69
MEAN			70

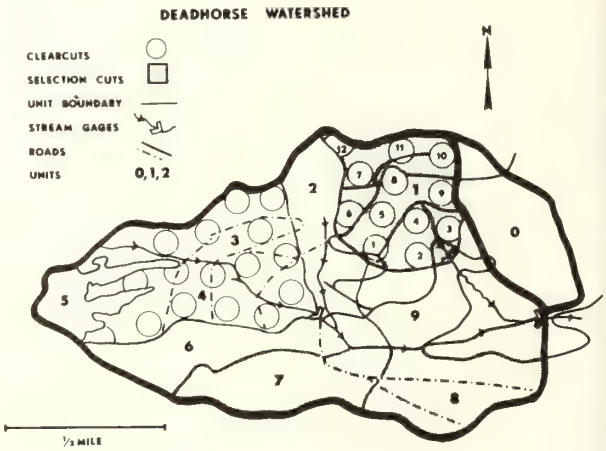
[1]ABOVE AN ASSUMED CONSTANT BASEFLOW OF 0.2 AND 0.1 CUBIC FOOT PER SECOND ON DEADHORSE AND LEXEN CREEKS, RESPECTIVELY.

Water Quality.—Natural flows from Deadhorse and Lexen Creek are generally pure. Concentrations of all chemical components are low, pH values near neutral, and temperatures very cold (0°-7°C).

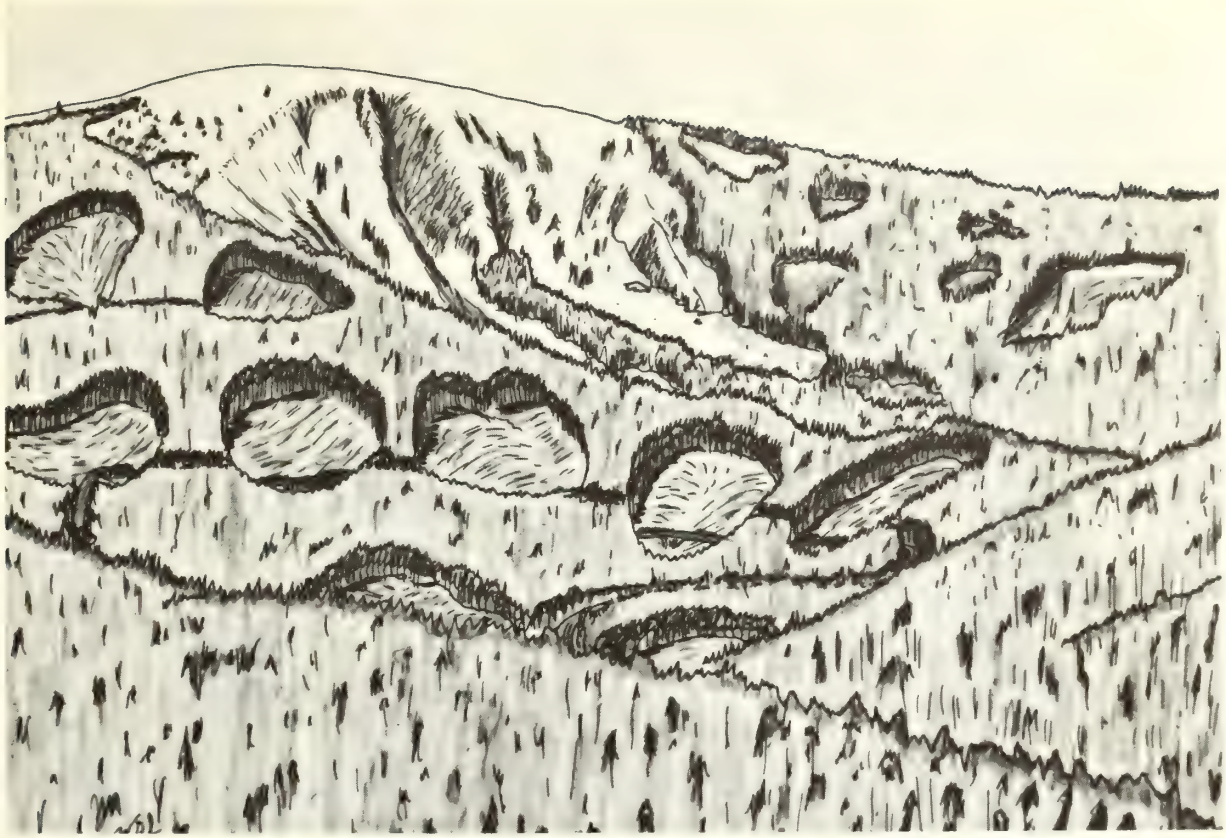
Timber Harvest

Approximately 1 mile of main access road was built in 1955 to harvest timber and construct stream gaging stations on Deadhorse Creek. Another 2.5 miles of main access road was constructed in 1970-1971, and about 1 mile of main access road was built in 1976. Approximately 0.3 mile of main access road and 2.5 miles of spur road will be constructed in 1977. Additional roads needed will be built as timber harvesting proceeds.

North Fork (Response Unit 1).—A patch cutting operation has been selected for the North Fork of Deadhorse Creek. Long-term simulation of the hydrologic impacts of this option indicate an optimum water yield increase of 1.5 to 2.0 inches annually from this lower south slope subunit. This cutting pattern also is a first step to placing the timber stand under management.



Under this alternative, about 35% of the old-growth timber, principally lodgepole pine, will be removed by clearcutting small openings, about 400 feet in diameter, dispersed over the subunit. Present plans call for recutting these openings every 30 years to maintain increased water yield. No immediate cutting is proposed for the remaining timber stand.



The road system to remove timber from this subunit will be completed in early summer of 1977, with cutting to begin and finish in 1977 also. All live trees down to 4 inches d.b.h. on the cut patches will be removed. Logging will be done by conventional methods—downhill skidding of logs. Logging slash will be lopped and scattered. An estimated 200,000 fbm of timber will be removed.

North Slope (Response Unit 8).—A three-cut shelterwood option has been selected for this north slope subunit. Long-term simulation of the hydrologic impact of this option indicates no increase in runoff. This cutting pattern also will be a first step to placing the timber stand under management.

Under this alternative, about 40% of the old-growth, mixed lodgepole pine—spruce-fir stand will be removed on an individual tree basis throughout the subunit. An additional 30% of the old growth will be harvested in 20 years, with the remainder harvested in 40 years.

Roads to remove this timber will be constructed in 1977. The first cutting will begin and be completed in 1979. All cutting will be on an individual tree basis. Logging and slash disposal will be by conventional methods.

Upper Basin (Response Units 3 and 4).—A patch cutting alternative has also been selected for the Upper Basin of Deadhorse Creek. Long-term simulation of the hydrologic impacts of this option indicate an optimum water yield increase of 1.5 to 2.5 inches annually.

Under this alternative, 30 to 40% of the old-growth, mixed pine–spruce-fir timber will be removed by clearcutting small openings (five to eight times tree height in diameter) scattered over the subunit. This option differs from the North Fork in that initial openings will be regenerated and allowed to grow to maturity. New openings will be cut in 30 years, with the last of the old growth removed 60 years after the first cut.

The road system to remove timber from this subunit will be constructed in 1978. Cutting will begin and be completed in 1981. Trees removed and logging will be similar to that on the North Fork.

Operational Watershed Management

Operational aspects of watershed management—collecting and analyzing data on stream flow, snow accumulation and disappearance, water quality, sediment yield, soil water movement, temperature, precipitation, and radiation—will continue on Deadhorse and Lexen Creeks. These data are needed to determine treatment responses and provide input to test the hydrologic simulation model.

Game Animals

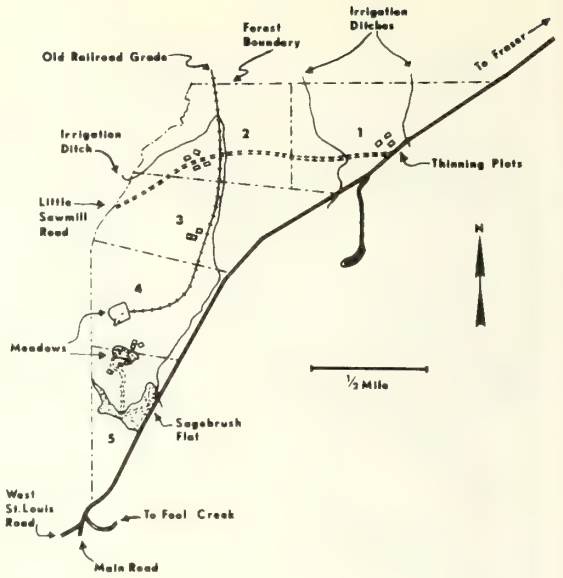
On all subunits scheduled for timber harvesting, use by mule deer, elk, and blue grouse is being sampled to determine impact of cutting timber on animal population density and distribution. Cover and composition of understory vegetation and biomass also is being sampled to determine response to timber harvesting options.

Nongame Birds and Small Mammals

Species and population densities of small mammals and nongame birds on subunits scheduled for timber harvest also are being inventoried to determine their responses to changes in habitat resulting from treatment. These data will provide information on habitat requirements of small mammals and birds that inhabit subalpine coniferous forests.

Levels of Growing Stock—Young Lodgepole Pine

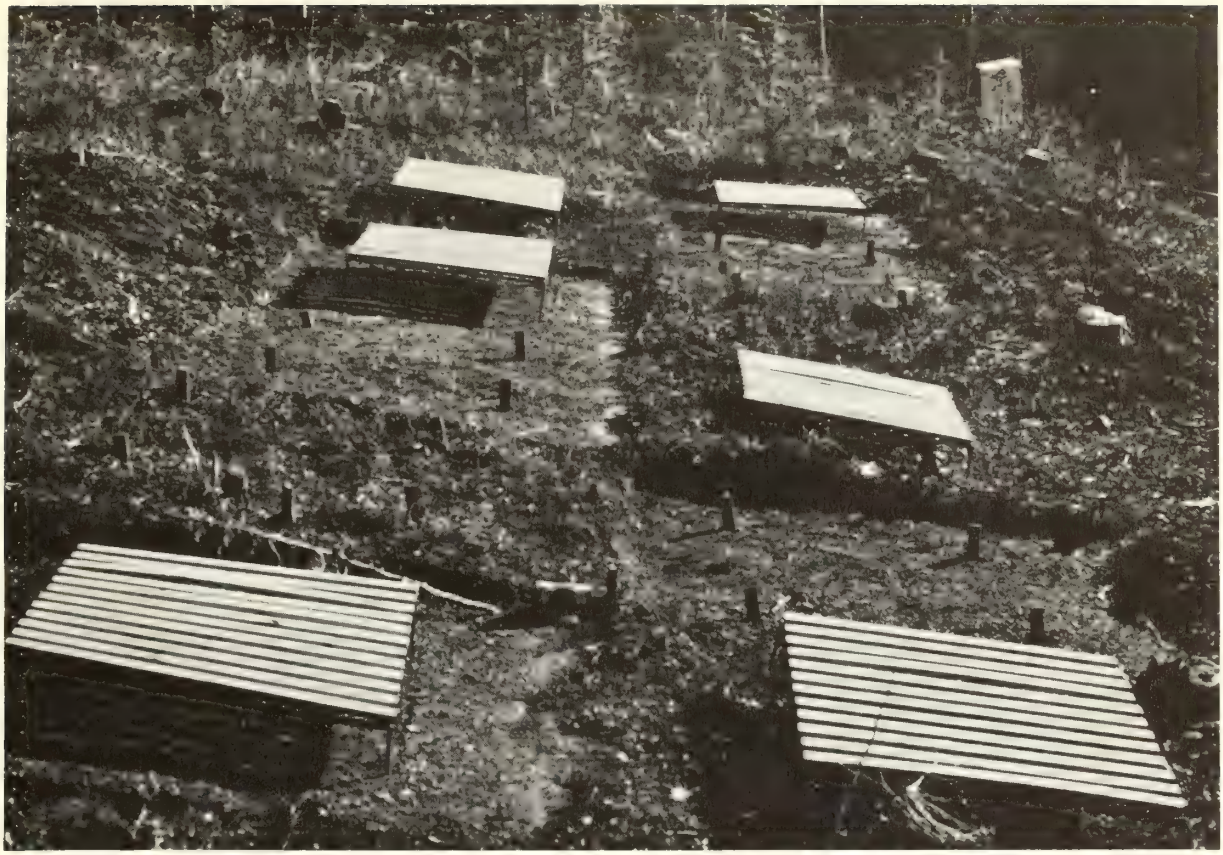
In 1975, a study was started in second-growth lodgepole pine stands on St. Louis Creek drainage to test different thinning levels. The study area was divided into five units, with one unit scheduled for thinning each year for 5 years. Within each unit, three 0.4-acre plots will be

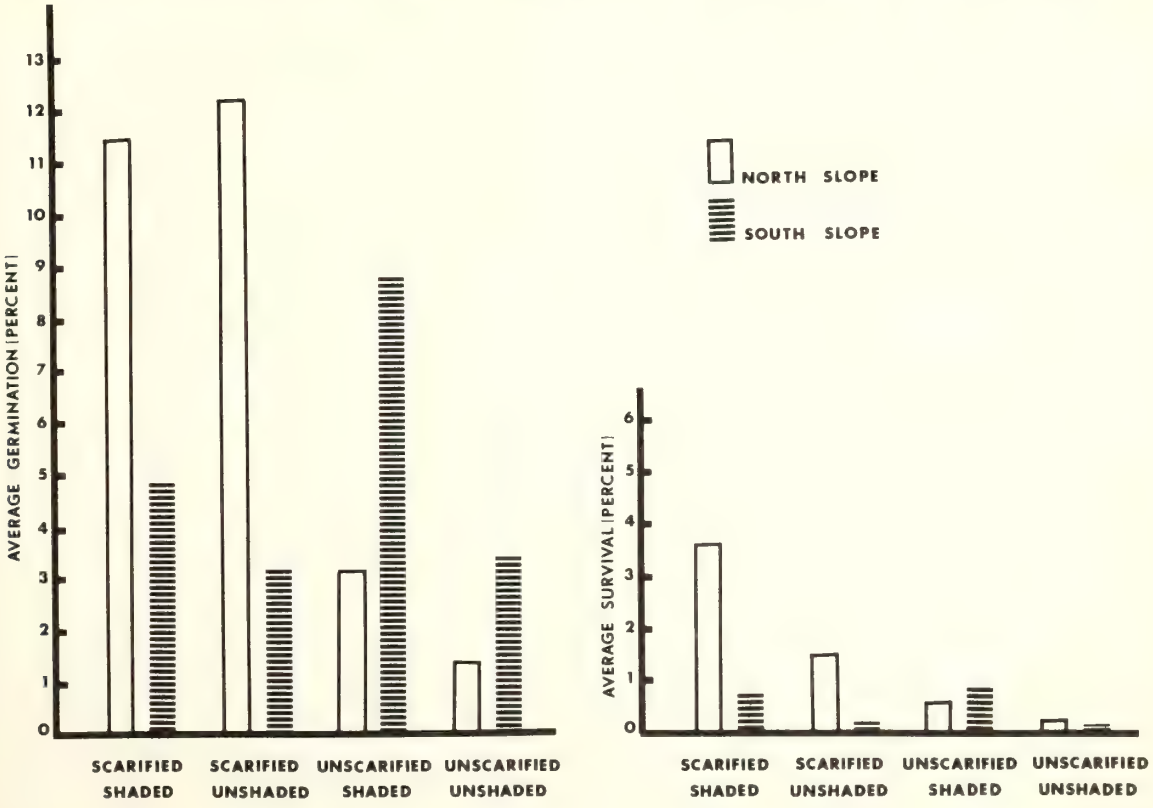


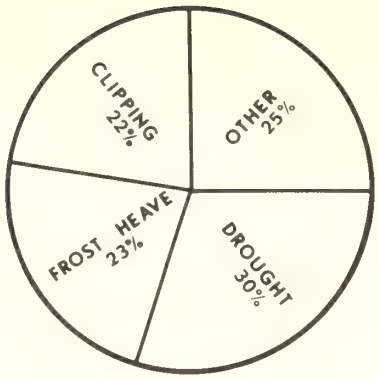
thinned from below, each to a different growing stock level (80, 100, 120). The first series of plots, in Unit 1, were thinned in 1976. The last series of plots, in Unit 5, will be thinned in 1981. Periodic remeasurement will provide information on stand growth at different stocking levels, rate of spread and intensification of dwarf mistletoe infection, population density and distribution of deer and elk in relation to overstory density, relative herbage production in relation to basal area of residual overstory, forage availability to animals, soil moisture withdrawal in relation to overstory density and depth below the soil surface, and seasonal progress of soil moisture depletion.

Environmental Factors Affecting Engelmann Spruce Regeneration

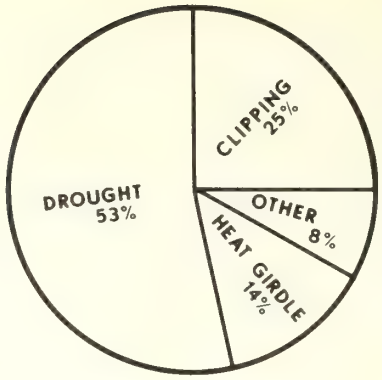
Two study areas were established in 1967 and 1968 to identify factors limiting spruce regeneration success, and determine cultural practices needed to provide an environment suitable for spruce regeneration. Study plots are located in two 3.5-acre clearcut openings at 10,500 feet elevation, one on a north slope of the Fool Creek drainage, the other on a south slope of the West St. Louis Creek drainage.




AVERAGE GERMINATION (PERCENT)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
SCARIFIED SHADED
SCARIFIED UNSHADED
UNSCARIFIED SHADED
UNSCARIFIED UNSHADED
NORTH SLOPE
SOUTH SLOPE
AVERAGE SURVIVAL (PERCENT)
0
1
2
3
4
5
6
SCARIFIED SHADED
SCARIFIED UNSHADED
UNSCARIFIED SHADED
UNSCARIFIED UNSHADED



NORTH SLOPE



SOUTH SLOPE

Each year, twelve 4 x 12 m seedbeds are prepared at each study site. Each set is composed of four seedbed treatments—scarified-shaded, scarified-unshaded, unscarified-shaded, and unscarified-unshaded—replicated three times each. Seed is sown each fall on the current set of seedbeds to simulate natural seedfall.

Five years of observation indicates that germination on the north slope is best on scarified-unshaded seedbeds and poorest on unscarified-unshaded seedbeds; survival is best on scarified-shaded seedbeds and poorest on unscarified-unshaded seedbeds. Nearly 80% of the germinating seedlings died, with most mortality caused by drought, frost heaving, and clipping by birds. Four years of observation indicates germination on south slopes is best on unscarified-shaded seedbeds and poorest on scarified-unshaded seedbeds; survival is best on unscarified seedbeds and poorest on scarified-unshaded seedbeds. About 90% of the germinating seedlings died, with most mortality caused by drought, clipping by birds, and heat girdle.

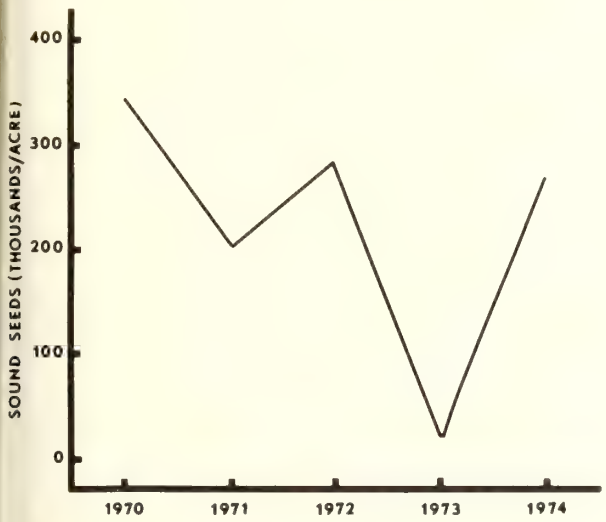
The most favorable and unfavorable conditions for Engelmann spruce regeneration success are summarized in the table below.

REGENERATION CONDITIONS

FAVORABLE		UNFAVORABLE
>600,000 SEED/HA	-SEED CROP-	<60,000 SEED/HA
NORTH	-ASPECT-	SOUTH
AMBIENT AIR >0°C NIGHT AND <25°C DAY; MAXIMUM SURFACE <30°C	-TEMPERATURES-	AMBIENT AIR <0°C NIGHT AND >25°C DAY; MAXIMUM SURFACE >30°C
>1.0 CM/WEEK	-PRECIPITATION-	<1.0 CM/WEEK
LIGHT-TEXTURED, SANDY-LOAM	-SOIL-	HEAVY-TEXTURED, CLAY-LOAM
50 PERCENT EXPOSED MINERAL SOIL	-SEEDBED-	10 PERCENT OR LESS EXPOSED MINERAL SOIL
40-60 PERCENT DEAD SHADE DUFF AND LITTER <5 CM LIGHT VEGETATIVE COVER		10 PERCENT OR LESS DEAD SHADE DUFF AND LITTER >5 CM HEAVY VEGETATIVE COVER
SEEDLINGS >12 WEEKS OLD BY MID-SEPT.	-SURVIVAL-	SEEDLINGS <12 WEEKS OLD BY MID-SEPT.
LOW POPULATION OF BIRDS AND RODENTS THAT EAT SEEDS AND SEEDLINGS		HIGH POPULATION OF BIRDS AND RODENTS THAT EAT SEEDS AND SEEDLINGS
PROTECTION FROM TRAMPLING		NO PROTECTION FROM TRAMPLING
SNOW COVER WHEN FROST-HEAVING CONDITIONS EXIST		NO SNOW COVER WHEN FROST-HEAVING CONDITIONS EXIST

Engelmann Spruce Seed Production

A long term study of Engelmann spruce seed production was started in 1968 on the Forest. By 1970, thirteen 0.4-acre plots were established at different elevations, aspects, etc. Good to heavy crops were produced during four of the first five years of observation, with some locations occasionally producing bumper crops. Much more seedfall data are needed to predict frequency of good seed crops and to identify the kinds of stands likely to provide good seed crops.



SIDELIGHTS

Facilities of the Fraser Experimental Forest are used occasionally for school training, undergraduate field work, field meetings of forestry and conservation societies, and Foreign Agriculture Service programs in forestry. Excellent examples nearby serve as on-the-ground illustrations of both beneficial and harmful practices in mountain agriculture.

Opportunities for graduate students to undertake fundamental research in conservation and use of natural resources are excellent. Arrangements may be made on a cooperative basis with the U.S. Forest Service through colleges, universities, foundations, or other interested groups.

Visitors are always welcome. To obtain more detailed published information about the experimental work, ask the resident scientists or send a request to Director, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect, Fort Collins, Colo. 80521.

APPENDIX A

Species List of Birds

Common Name	Scientific Name
MIGRATORY BIRDS	
Mallard	*Anas platyrhynchos*
Teal	*Anas* spp.
Golden eagle	*Aquila chrysaetos*
American kestrel	*Falco sparverius*
Spotted sandpiper	*Actitis macularia*
Mourning dove	*Zenaida macroura*
Rufous hummingbird	*Selasphorus rufus*
Black-billed magpie	*Pica pica*
Clark's nutcracker	*Nucifraga columbiana*
Black-capped chickadee	*Parus atricapillus*
Mountain bluebird	*Sialia currucoides*
Red-winged blackbird	*Agelaius phoeniceus*
SEASONAL NESTING BIRDS	
Goshawk	*Accipiter gentilis*
Sharp-skinned hawk	*Accipiter striatus*
Marsh hawk	*Circus cyaneus*
Red-tailed hawk	*Buteo jamaicensis*
Screech owl	*Otus asio*
Great horned owl	*Bubo virginianus*
Common nighthawk	*Chordeiles minor*
Broad-tailed hummingbird	*Selasphorus platycercus*
Common flicker	*Colaptes auratus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Hammond's flycatcher	*Empidonax hammondii*

Western flycatcher	*Empidonax difficilis*
Western wood pewee	*Contopus sordidulus*
Olive-sided flycatcher	*Nuttallornis borealis*
Horned lark	*Eremophilia alpestris*
Steller's jay	*Cyanocitta stelleri*
Common crow	*Corvus brachyrhynchos*
Dipper	*Cinclus mexicanus*
Red-breasted nuthatch	*Sitta canadensis*
Brown creeper	*Certhia familiaris*
American robin	*Turdus migratorius*
Townsend's solitaire	*Myadestes townsendi*
Hermit thrush	*Catharus guttatus*
Gold-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Regulus calendula*
Yellow-rumped warbler	*Dendroica coronata*
Wilson's warbler	*Wilsonia pusilla*
House finch	*Carpodacus mexicanus*
Pine grosbeak	*Pinicola enucleator*
Pine siskin	*Carduelis pinus*
Red crossbill	*Loxia curvirostra*
Gray-headed junco	*Junco caniceps*
White-crowned sparrow	*Zonotrichia leucophrys*

YEARLY RESIDENT BIRDS

Blue grouse	*Dendragapus obscurus*
White-tailed ptarmigan	*Lagopus leucurus*
Hairy woodpecker	*Picoides villosus*
Downy woodpecker	*Picoides pubescens*
Northern three-toed woodpecker	*Picoides tridactylus*
Gray jay	*Perisoreus canadensis*
Common raven	*Corvus corax*
Mountain chickadee	*Parus gambeli*

APPENDIX B
Species List of Mammals

Common Name	**Scientific Name**
Vagrant shrew	*Sorex vagrans*
Northern watershrew	*Sorex palustris*
Masked shrew	*Sorex cinereus*
Little brown myotis (bat)	*Myotis lucifugus*
Black bear	*Ursus americanus*
Marten	*Martes americana*
Longtail weasel	*Mustela frenata*
Shorttail weasel (rare)	*Mustela erminea*
Mink (rare)	*Mustela vison*
Striped skunk	*Mephitis mephitis*
Badger (occasional)	*Taxidea taxus*
Red fox	*Vulpes fulva*
Coyote	*Canis latrans*
Mountain Lion (rare)	*Felis concolor*
Bobcat	*Lynx rufus*
Yellowbelly marmot	*Marmota flaviventris*
Golden mantled squirrel	*Citellus lateralis*
Least chipmunk	*Eutamias minimus*
Colorado chipmunk (questionable)	*Eutamias quadrivittatus*
Uinta chipmunk	*Eutamias umbrinus*
Spruce squirrel	*Tamiasciurus fremonti*
Northern pocket gopher	*Thomomys talpoides*
Deer mouse	*Peromyscus maniculatus*
Bushytail woodrat	*Neotoma cinerea*
Mountain phenacomys (Heather vole)	*Phenacomys intermedius*
Boreal redback vole	*Clethrionomys gapperi*
Montane vole	*Microtus montanus*
Long-tailed vole	*Microtus longicaudus*
Western jumping mouse	*Zapus princeps*
Muskrat	*Ondatra zibethica*
Beaver	*Castor canadensis*
Porcupine	*Erethizon dorsatum*
Pika	*Ochotona princeps*
Snowshoe hare	*Lepus americanus*
Elk	*Cervus canadensis*
Mule deer	*Odocoileus hemionus*

Alexander, Robert R. and Ross K. Watkins. 1977. The Fraser Experimental Forest, Colorado. USDA For. Serv. Gen. Tech. Rep. RM-40, 32 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

This report provides a general overview of work done on the Fraser Experimental Forest. It replaces Station Paper No. 8, published in 1952 and revised by L. D. Love in 1960. Included are descriptions of physical features and resource values, and highlights of past and current research programs.

Keywords: Forest regeneration, watershed management, wildlife habitat.

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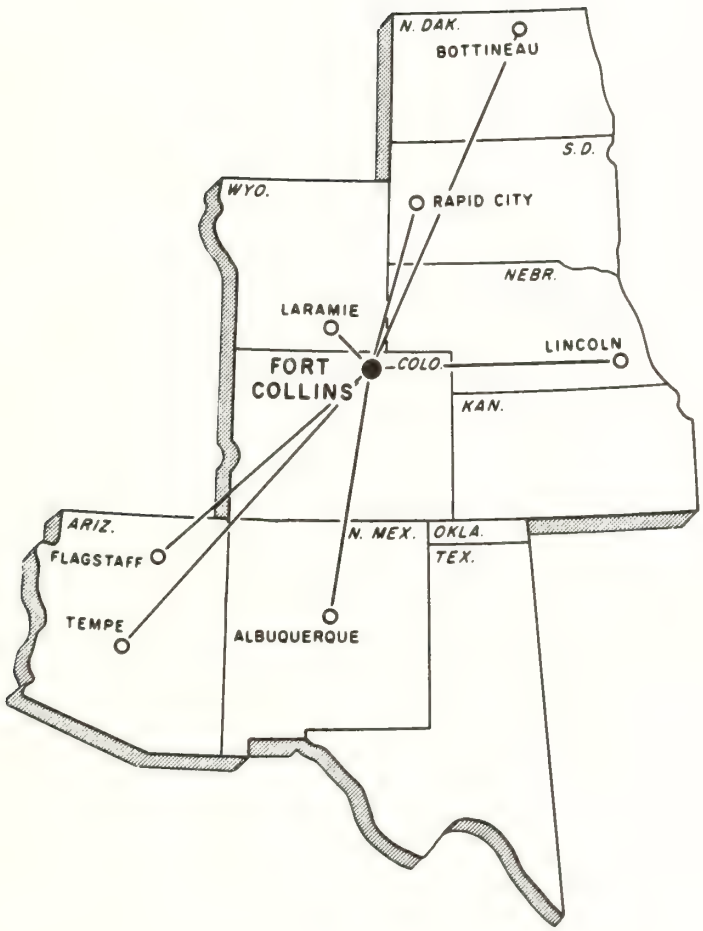
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The Fraser Experimental Forest is a research unit of the Rocky Mountain Forest and Range Experiment Station, which is maintained in cooperation with the Colorado State University at Fort Collins, Colorado



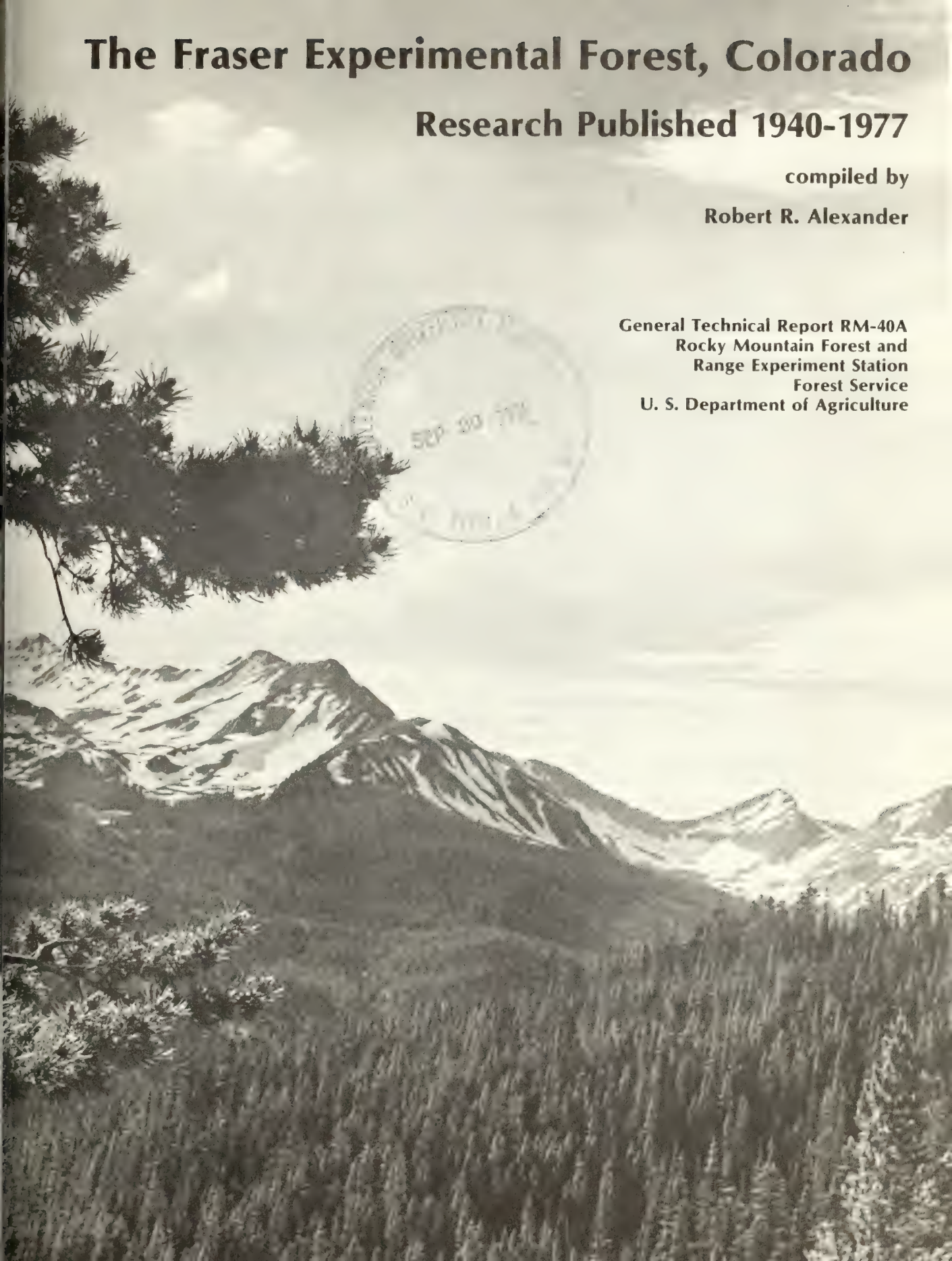
The Fraser Experimental Forest, Colorado

Research Published 1940-1977

compiled by

Robert R. Alexander

General Technical Report RM-40A
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U. S. Department of Agriculture



Abstract

General Technical Report RM-40-A lists all publications, Ph.D. Dissertations, and Masters Theses by subject matter that have originated from research at the Fraser Experimental Forest from 1940 through 1977. It supplements Gen. Tech. Rep. RM-40, "The Fraser Experimental Forest, Colorado," issued September 1977, which describes the physical and biological characteristics of the Forest, past research accomplishments, and current research programs.

ERRATA

The following errors have been noted in General Technical Report RM-40A, "The Fraser Experimental Forest, Colorado: Research Published 1940-1977."

p. 3, 2nd column: Garstka, W. H., F. A. Bertle, and E. G. Dunford. Correct entry should read Garstka, W. U., F. A. Bertle, and E. G. Dunford.

p. 4, 1st column: Goodell, B. C. Correct pagination should read p. 477-482.

p. 4, 1st column: Hoover, Marvin E. Correct entry should read Hoover, Marvin D.

p. 4, 1st column: insert additional entry.
Hoover, Marvin D. 1958. Vegetation and land-use effects. Am. Geophys. Union Trans. 39:519. (Abstr.)

p. 7, 2nd column: Wallmo, O. C. Correct title should read "Response of deer to alternate-strip cutting. . ."

p. 8, 1st column: Noble, Daniel L. Correct title should read "Natural regeneration of Engelmann spruce. . ."

p. 8, 1st column: Ronco, Frank. Correct title should read "The influence of high light intensity on the survival of planted Engelmann spruce."

p. 9, 1st column: Schultz, Robert W. Correct title should read "The use of snowmelt lysimeters for estimating the temporal and spatial distribution of snowmelt at Fraser Experimental Forest, Colorado."

General Technical Report RM-40A

THE FRASER EXPERIMENTAL FOREST, COLORADO

Research Published 1940-1977

compiled by
Robert R. Alexander,
Chief Silviculturist and Project Leader
Rocky Mountain Forest and Range Experiment Station[1]

[1]*Central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

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The Fraser Experimental Forest, Colorado

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Publications[2]

Timber Management

Alexander, Robert R. 1954. Mortality following partial cutting in virgin lodgepole pine. U. S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 16, 9 p. Fort Collins, Colo.

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[2]*Periodical abbreviations are based on those of the American Standards Institute at the time the project began. All contributions by the same author have been listed together, although some articles were published with initials only, and others have used full names.*

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APPENDIX

List of Ph.D. Dissertations and Master Theses

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Keywords: Watershed management, timber management, forest products, atmospheric sciences.

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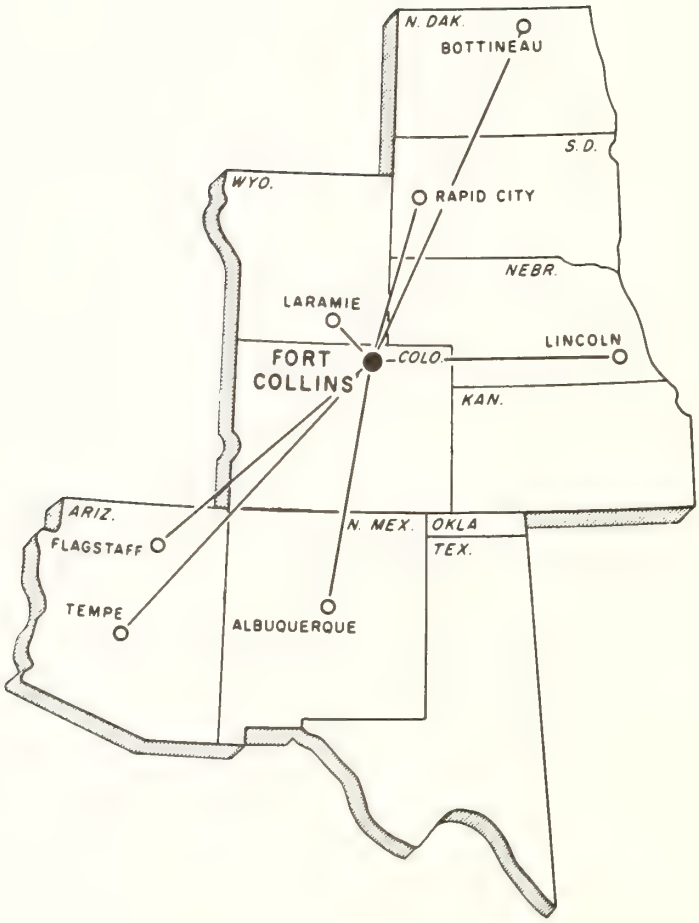
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Supplement to: Biotic Communities of the Southwest
USDA General Technical Report RM-41

David E. Brown, Charles H. Lowe, and Charles P. Pase[1]

This map illustrates, at a scale of 1:1,000,000, the major upland biotic communities (=biomes) of the "American Southwest". We consider the natural Southwest region that area shared between the U.S. and adjacent Mexico from longitudes 103° to 118° and from latitude 37° 31' to latitude 27°, including all or parts of the states of Arizona, New Mexico, Texas, Colorado, Utah, Nevada, and California and all or part of Baja California, Sonora, Chihuahua, and Coahuila.

The 27 biotic communities identified are those presented in the hierarchical ecosystem classification developed by Brown and Lowe (1974a, 1974b) and Brown, Lowe, and Pase (1977). While these units are described in terms of potential natural vegetation, faunal components also are considered. The following biotic units are shown:

ALPINE TUNDRA
PETRAN (ROCKY MOUNTAIN) SUBALPINE CONIFER FOREST
SIERRAN SUBALPINE CONIFER FOREST
PETRAN MONTANE CONIFER FOREST
SIERRAN MONTANE CONIFER FOREST
SINALOAN DECIDUOUS FOREST
GREAT BASIN CONIFER WOODLAND
MADREAN EVERGREEN WOODLAND
CALIFORNIAN EVERGREEN WOODLAND
GREAT BASIN MONTANE SCRUBLAND
CALIFORNIAN CHAPARRAL
INTERIOR CHAPARRAL
CALIFORNIAN COASTALSCRUB
SINALOAN THORNSCRUB
SUBALPINE GRASSLANDS
PLAINS GRASSLAND and PLAINS GRASSLAND with Shinnery Oak
CALIFORNIAN VALLEY GRASSLAND
SEMIDESERT GRASSLAND
GREAT BASIN DESERTSCRUB
MOHAVE DESERTSCRUB
CHIHUAHUAN DESERTSCRUB
SONORAN DESERTSCRUB
- Arizona Upland Subdivision
- Lower Colorado River Subdivision
- Central Gulf Coast Subdivision
- Plains of Sonora Subdivision
- Vizcaiano Subdivision

[1] *Brown, Small Game Supervisor, Ariz. Game and Fish; Lowe, Professor, Dep. of Ecology, Univ. of Ariz.; and Pase, Research Forester, Rocky Mt. For. and Range Exp. Stn. with Ariz. State Univ. Station's central headquarters maintained at Fort Collins, in cooperation with Colo. State Univ.*

Incorporated in the classification system are contributions of plant geographers and ecologists in general usage throughout the Southwest, including those of Watson 1912; Shantz and Zon 1924; Morris 1935; Muller 1937, 1947; Gentry 1942; Shreeve 1942, 1951; Munz and Keck 1949, 1950; Nichol 1952; Benson and Darrow 1954; Castetter 1956; Shelford 1963; Kuchler 1964; Lowe 1964; Bradley and Deacon 1965; Flores et al. 1971; and Ornduff 1974.

The map base consisted of Sectional Aeronautical Charts, (scale 1:1,000,000) provided without navigational enhancement by the U.S. Department of Commerce. The choice of color for the various biotic communities follows the ecological color scheme proposed by Gaussen (1953) where dark, cold colors denote the wetter, colder ecosystems, light shades represent the more arid areas, and bright colors signify warm areas.

The boundaries of the biotic units were determined after extensive field investigation and consultation with all available published sources and from aerial photos, where feasible. We are particularly indebted to Rodney Engard and H. Scott Gentry, Desert Botanical Gardens, Phoenix; R. V. Moran, Balboa Park Natural History Museum, San Diego; Killiam Roever, Chemargo, Phoenix; Raymond M. Turner, U.S. Geological Survey, Tucson; R. H. Wauer, U.S. National Park Service, Santa Fe; Tom Wendt, University of Texas, Austin; And Bart Warnock, Sul Ross University, Alpine, Texas, who shared their special field knowledge and otherwise provided assistance.

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ERRATA

	Latitude	Longitude	Error	Corrected
1.	36° 49' N	105° 34' W	(pink)	Great Basin Montane Scrub
2.	35° 53' N	109° 6' W	(white)	Plains Grassland
3.	34° 27' N	109° 46' W	(white)	Great Basin Grassland
4.	34° 12' N	111° 51' W	Plains of Sonora	Interior Chaparral
5.	33° 19' N	109° 24' W	Lower Colorado River Subdivision	Madrean Evergreen Woodland
6.	33° 19' N	107° 12' W	(green)	Desert Grassland
7.	32° 52' N	107° 12' W	(green)	Desert Grassland
8.	32° 14' N	103° W	(white)	Plains Grassland
9.	30° 57' N	107° 6' W	Mohave Desertscrub	Chichuahuan Desertscrub
10.	29° 15' N	107° 52' W	(white)	Madrean Evergreen Woodland
11.	27° 52' N	109° 21' W	Lower Colorado River Subdivision	Sinaloan Thronscrub

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Comments and suggestions are solicited from field personnel. Please send suggestions to:

Rocky Mountain Forest and Range Experiment Station
Forest Sciences Laboratory
Arizona State University
Tempe, Arizona 85281

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Climatological Data from the Berthoud Pass Area of Colorado

Arthur Judson



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Abstract

Monthly, daily, and hourly meteorological data, collected irregularly from 1926 through 1977, are presented in tabular form. Complete year long data on temperature, precipitation, snow depth, and wind from three mountain sites surrounding Berthoud Pass are analyzed for the period 1963 through 1975.

USDA Forest Service
General Technical Report RM-42

October 1977

Climatological Data From the Berthoud Pass Area of Colorado

Arthur Judson, Meteorologist

Rocky Mountain Forest and Range Experiment Station[1]

[1]*Central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Climatological Data From the Berthoud Pass Area of Colorado

Arthur Judson

The Forest Service avalanche station at Berthoud Pass (BPS), Colorado provides weather, snow, and avalanche data utilized in avalanche research and public warnings. As one of 40 stations on the USDA Forest Service Westwide Avalanche Reporting Network (Judson 1970), BPS weather instruments continuously monitor precipitation, temperature, dewpoint, wind, and atmospheric pressure. A paid observer measures snowfall and its water equivalent, snow depth, rainfall, and temperature daily.

This paper presents BPS snowfall data from 1926 through 1977, maximum snow depth from 1931 through 1977, precipitation from 1949 through 1977, and temperature, snow depth, and wind data from 1963 through 1975. Mean hourly precipitation from November 1951 through April 1976 has been included.

The BPS station has one of the more complete high mountain weather records in North America. Data collection that began in 1926, continued intermittently through 1962, and was published by Judson in 1965. Year-round data collection began in 1963 in conjunction with the Forest Service's avalanche research program.

The data are published in response to numerous requests for information on the high mountain environment. The data are relevant to avalanche research, planning, and control, and to the myriad of problems associated with development of recreation, industry, water resources, and energy needs of Colorado's rapidly growing Front Range corridor. The data are also being used to develop a dynamic simulation model of avalanche danger.

Climatic data for other mountain areas in Colorado may be found in Armstrong and Ives (1976), Avalanche Notes[2], Barry (1972), Bates and Henry (1922, 1928), Haeffner (1971), Marr (1967), Marr et al. (1968a, 1968b), and Rhea (1966, 1968).

Location

Berthoud Pass is in north central Colorado, 45 miles west of Denver, (fig. 1). Precipitation, snow depth, and temperature are measured in a small forest opening one-quarter mile northwest of the pass (fig. 2). The clearing, referred to as Q-12 park, was named after the Leopold Stevens Q-12 recording precipitation gage used there in the early 1950s. Site elevation is 11, 315 feet m.s.l. at latitude 39° 48'N and longitude 105° 45'W.

Wind data are measured at three locations representative of winds found near and above timberline in the Front Range. The 60-foot-high Fool Creek windtower (fig. 3), ground elevation 10,620 feet (Haeffner 1971), is 6 miles northwest of the pass in the Fraser Experimental Forest. Records from this below-timberline station are recorded all year. The Berthoud Pass chairlift wind sensors are located on a 33-foot tower one-half mile west of the pass (fig. 4). Ground elevation at this above-timberline site is 11,880 feet m.s.l. The third wind station is located 1 mile

[2]*Avalanche Notes (1973-77), are a series of unpublished monthly weather and avalanche summaries from the Forest Service Westwide Reporting Network. The reports are on file at the Rocky Mountain Station's Mountain Snow and Avalanche Research Project files. Summary data from 1967-73 are in the same file, under the heading: "U.S. Forest Service, Alpine Snow and Avalanche Research Project, R.M. Station, Fort Collins, Colo., Summary of Weather and Snow Conditions."*

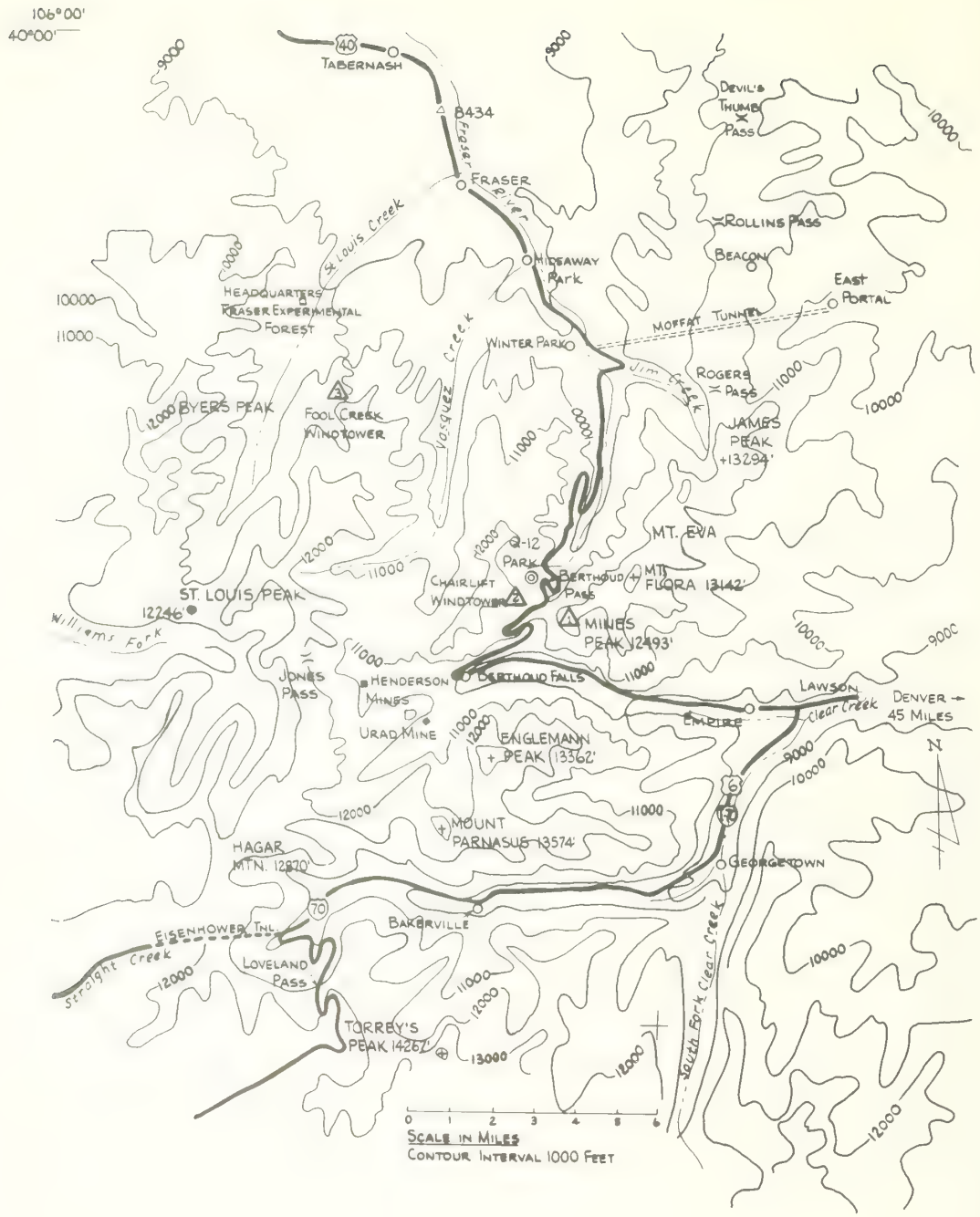


Figure 1.— Map of the Berthoud Pass area in northcentral Colorado. Wind stations are located by triangles at Fool Creek in the Fraser Experimental Forest, at the top terminal of the Berthoud Pass chairlift, and on the summit of Mines Peak. Temperature and precipitation data are taken at Q-12 Park, indicated by the double circle, one-quarter mile northwest of the pass.



Figure 2.—Instruments at the climatological data site in Q-12 Park. Forest Service gages on the tower (right) are 14 feet above the ground; instrument shelter (center) is adjustable for changing snow depths; precipitation gages and building (left) are part of the Soil Conservation Service's Snotel Meteor Burst reporting network.



Figure 3.—Wind sensors on the 60-foot tower at Fool Creek in the Fraser Experimental Forest are 10,680 feet above sea level. Sensors in this 1951 picture were replaced with standard F-420C units in the late 1960s.



Figure 4.—Wind sensors on the 33-foot tower above the upper terminal of the Berthoud Pass chairlift. Icing at this site is rare; ground elevation is 11,880 feet mean sea level.

east of the pass on the 12,493-foot summit of Colorado Mines Peak (fig. 5). Wind instruments at this exposed site are mounted on a 38-foot tower and require de-icing equipment (Judson 1971).

Data from both Mines Peak and the chairlift wind sites are telemetered to recorders located in a building at the pass. Wind and blowing snow data from Mines Peak are presently telemetered to the Avalanche Warning Center offices at the Rocky Mountain Station in Fort Collins, Colo. (fig. 6, 7). Frequent lightning precludes collection of wind data at the chairlift and Mines Peak in summer. Complete descriptions of the BPS instrument sites are given by Judson (1965).

Measurements and Data Reduction

Precipitation was measured in standard, unshielded, 8-inch cans and recording gages. An observer measured 24-hour snowfall on a white snowboard daily, and obtained water equivalent of the snow by taking cores on the board and weighing the samples. Total snow depth on the ground was read to the nearest inch from a 12-foot stake. Temperature extremes were obtained from maximum-minimum thermometers in a standard instrument shelter, suspended inside a metal frame. This arrangement allows for periodic height adjustment, so the shelter can be kept the proper distance above the snow surface (fig. 8). Precipitation and temperature measurements were taken from the 24 hours ending at 8 a.m. Mountain Standard Time. National Weather Service F-420C windspeed and direction sensors were used at the three wind sites.



Figure 5.—Wind sensors on the 38-foot Colorado State Patrol communications tower on the 12,495-foot summit of Mines Peak. Heat from three 300-watt incandescent lamps, controlled by a switching circuit at the pass, prevents anemometer icing; rime ice frequently occurs at this location.



Figure 6.—Project Scientist R. A. Schmidt, calibrating snow particle counter at the telemetry site on Mines Peak. Sensor is 50 centimeters above-ground; top of blowing snow layer is just above sensor. Wind sensors are 33-feet above ground on the north side of Mines Peak. Northwest view shows Berthoud Pass highway, Fraser River Valley, and west flank of Colorado's Front Range.

Observers visually averaged hourly windspeed and direction data from the 1½-inch per hour analog strip charts. Peak gusts were tabulated directly from the charts.

All data were transferred to forms, keypunched, and put on a magnetic tape. Numerous subroutines were written to find and eliminate errors, and manual data checks were routinely made as a second verification. Means, extremes, and summations are given for precipitation and snowfall, while means and extremes are given for temperature and wind. The letter "G" following the hourly windspeed, indicates conditions when the majority of instantaneous peaks and lulls deviated from the mean by more than 15 miles per hour.

Applicability

Temperatures recorded at BPS closely represent conditions found throughout the Colorado mountains near timberline. The precipitation regime is typical of conditions in the high mountains of the Front Range, although variations of greater than 50% may occur at similar elevations, depending on orographic effects. The snowfall season is long, usually beginning in late August and ending in late June. Winds measured on Mines Peak are strong, averaging 28.4 miles per hour from November through April, and are typical of those found along the exposed sections of the high mountains in the Front Range. The consistently strong winter winds along the Front Range crest make it a potential site for wind-generated electrical power. Icing due to rime is relatively light, but is present for about 800 hours each winter (Judson 1971).

Winter Drought 1976-77

October 1976 through February 1977 precipitation at BPS was the third driest period since year long records began in 1961. Only 1963-64 and 1965-66 were drier:

	October-February		
Year	**Precip.** *Inches*	**Snowfall** *Inches*	**Density** *Percent*
61-62	15.20	226.0	7
62-63	11.77	192.0	6
63-64	9.86	139.0	7
64-65	15.66	242.5	6
65-66	10.42	173.0	6
66-67	14.95	218.7	7
67-68	16.52	251.1	7
68-69	13.98	182.5	8
69-70	21.10	305.5	7
70-71	19.65	262.3	7
71-72	17.11	229.0	7
72-73	12.67	167.5	8
73-74	17.51	229.5	8
74-75	16.33	210.0	8
75-76	13.43	173.0	8
76-77	10.73	141.0	8

The present drought at BPS is drier than winter 1933-34. According to March 1, 1977 Soil Conservation Snow Survey (SCS) measurements at "Berthoud Summit" snow course, which crosses the BPS site, and "Berthoud Pass" snow course, 4 miles north of BPS, the winter snowpack is the lowest on record. "Berthoud Summit" SCS data began in 1951, while "Berthoud Pass" SCS data began in 1936. Considering all data sources, the present drought is one of the worst since 1930. According to Jack Washicheck[3], SCS snow survey supervisor for the State, 75% of Colorado's snow courses on March 1, 1977 were the lowest on record.

Colorado's ski industry suffered accordingly, the winter wheat crop is in trouble, and prospects for summer water supplies are poor. This year's drought compares with the dust bowl days of the early 1930s. The socioeconomic impact on Colorado may well be the worst on record; never before have there been so many people faced with severe water shortages. This drought focuses the need for long term precipitation records, not just on the plains and in the mountain valleys, but in the high mountains above 10,000 feet, where winter snowfall provides the bulk of the spring runoff. Presently, there are only three high mountain precipitation stations in the 54,000 square miles of mountainous terrain in Colorado.

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[3] *Personal communication, March 1977.*

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Figure 7.—Project Scientist R. A. Sommerfeld taking message in the Avalanche Warning Center office in Fort Collins. Picture shows: (left) real-time telemetered display of data from Mines Peak; (left of center) National Weather Service teletype; and (center) Code-a-Phone.



Figure 8.—Instrument shelter in Q-12 Park (right) is mounted inside frame so the base can be adjusted for changing snow depths. Building houses telemetry equipment for the Soil Conservation Service's Snotel Meteor Burst reporting network.

Data Presentation

Data are presented in the following series of summary tables:

Types	Tables	Years	Page
Summary of data 1963-75	1	13	8
Monthly and seasonal snowfall 1926-77	1	38	9
Maximum monthly snow depth	1	44	10
Monthly and seasonal precipitation 1949-77	1	28	11
Daily precipitation (inches of water)	13	13	12
Daily temperature extremes	13	13	19
24-hour new snowfall and snow depth on the ground	13	13	26
Fool Creek Wind — Jan.-Dec.			
Prevailing wind direction and mean daily wind speed	8	8	33
Maximum hourly winds	8	8	38
Minimum hourly winds	8	8	43
Chairlift Wind — Oct.-May			
Prevailing wind direction and mean daily wind speed	13	13	48
Maximum hourly winds	13	13	55
Minimum hourly winds	13	13	62
Daily peak gusts — Nov.-Apr.	7	7	69
Mines Peak Wind — Oct.-May			
Prevailing wind direction and mean daily windspeed	8	8	73
Maximum hourly winds	8	8	78
Minimum hourly winds	8	8	83
Daily peak gusts — Nov.-Apr.	7	7	88
BPS mean annual hourly precipitation by days — Nov.-Apr.	6	26	92
Total	150		

Summary of climatological data from the Berthoud Pass area, 1963-75[1/]

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Temperature (degrees F.):													
Mean	10	11	17	24	34	43	51	49	41	32	20	12	29
Mean maximum	20	23	28	35	46	54	62	60	52	43	30	22	40
Mean minimum	1	1	6	13	24	32	39	38	30	21	10	2	18
Maximum	42	42	50	55	62	70	76	72	68	62	54	47	76
Minimum	-32	-22	-24	-12	-3	14	26	25	4	-5	-15	-22	-32
Precipitation (inches):													
Mean	3.45	3.19	3.72	4.20	2.86	2.72	2.54	2.65	2.44	2.15	3.25	3.42	36.59
Maximum	4.80	5.12	6.14	6.43	6.10	5.23	5.98	6.20	3.77	6.84	5.15	6.79	44.23
Minimum	1.24	1.60	1.62	1.89	.59	.45	1.02	1.18	1.16	.74	1.39	1.65	32.22
Maximum 24 hour	1.24	1.27	1.12	1.32	3.06	1.36	1.19	.82	1.29	1.20	1.31	1.58	3.06
Mean no. of days $\geq$ .10	11	11	12	11	8	7	8	8	7	6	10	11	110
Mean no. of days $\geq$ .50	1	1	2	2	1	1	1	1	1	1	2	1	15
Snowfall (inches):													
Mean	47.1	46.5	53.6	53.5	27.0	13.4	0	0	11.1	25.8	48.8	48.4	375.2
Maximum	75.3	76.6	92.8	75.0	54.0	44.0	0	3.0	34.5	90.0	78.5	86.5	477.0
Minimum	16.5	28.0	26.5	24.0	1.5	0	0	0	0	6.4	18.0	28.5	251.5
Maximum 24 hour	12.0	13.0	15.0	15.0	30.0	16.0	0	3.0	18.0	16.0	18.0	17.0	30.0
Mean no. of days $\geq$ a trace	17	16	17	15	9	4	0	0	4	8	14	17	121
Mean no. of days $\geq$ 6 in.	2	2	3	3	1	1	0	0	0	1	3	2	18
New Snowfall Density (percent):													
Mean	7	7	7	8	10	17		20	13	8	7	7	
Snowdepth (inches):													
Mean depth on the 1st/15th	35/39	46/51	56/61	63/64	61/52	30/12	0/0	0/0	0/0	0/3	9/14	19/26	
Maximum	66	74	90	93	85	58	0	3	18	27	40	56	93
Minimum	17	29	41	33	0	0	0	0	0	0	0	8	0
Windspeed (miles per hour):													
Fool Creek													
Mean	10.7	7.7	9.3	8.7	7.9	7.3	5.1	6.5	6.9	6.2	7.4	7.0	7.6
Maximum hour	47	37	45	38	34	30	40	25	40	40	50	46	50
Berthoud Pass Chairlift													
Mean	16.6	15.2	15.2	15.1	12.9						14.4	15.3	
Maximum hour	66	54	56	50	47						50	56	66
Peak gust	106	84	96	72							100	97	106
Mines Peak													
Mean	34.5	28.5	27.6	23.3	18.8						26.6	30.0	
Maximum hour	100	85	77	71	57						88	90	100
Peak gust	127	120	115	100							130	116	130

[1/] Wind data for Fool Creek are for Jan-Dec 1968-75; Berthoud Pass Chairlift wind data are for Oct-May 1963-64 through 1975-76; Mines Peak data cover Oct-May 1968-69 through 1975-76. Peak gust data cover Nov-April 1969-70 through 1975-76.

Monthly and seasonal snowfall (inches) at Berthoud Pass, Colorado 1926-77

Season	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Total
1926-27	6.0	20.0	77.0	56.0	41.0	84.0							
1928-29		21.0	42.0	31.0									
1931-32	0	12.0	39.0	21.0	47.0	43.0	141.0	71.0	29.0	0			
1932-33	2.0	41.0	47.0	52.0	63.0	33.0	65.0	154.0	50.0	0			
1933-34	6.0	4.0	8.0	29.0	26.0	128.0	66.0	21.0	30.0	0			
1934-35	8.0	3.0	54.0	58.0	26.0	28.0	57.0	128.0	71.0	6.0			
1935-36	7.0	47.0	41.0	45.0	101.0	95.0	69.0	21.0	35.0	2.0	6.0		
1936-37	23.0	25.0	21.0	46.0	43.0	76.0	59.0	50.0	10.0	9.0			
1937-38	14.0	35.0	72.0	64.0	55.0	19.0	63.0	73.0	37.0	0			
1938-39	0	4.0	45.0	60.0	48.0	69.0	80.0	55.0	15.0	0			
1949-50		26.0				36.0	42.0		28.0				
1950-51			70.0	50.0	29.0	45.0	16.0	56.0					
1951-52			40.0	81.0	40.0	43.0	43.0	58.0					
1952-53			28.0	45.0	80.0	47.0	50.0	50.0					
1953-54			54.0	47.0	19.0	33.0	61.0	19.0					
1954-55			41.0	29.0	38.0	26.0	71.0	35.0					
1955-56			66.0	63.0	90.0	62.0	36.0	64.0					
1956-57			33.0	44.0	93.0	43.0	79.0	122.0	54.0				
1957-58	3.0	7.0	38.0	79.0	53.0	72.0	75.0	66.0					
1958-59			30.0	71.0	51.0	72.0	56.0	36.0					
1959-60	36.0	31.0	30.0	16.0	42.0	67.0	72.0	32.0					
1960-61			22.0	46.0	25.0	36.0	57.0	64.0			8.0		
1961-62	72.0	26.0	33.0	54.0	63.0	50.0	33.0	74.0	24.0	8.0	0	2.0	439.0
1962-63	3.0	5.0	26.0	40.0	57.0	64.0	47.0	23.0	2.0	9.0	0	0	276.0
1963-64	T	8.0	18.0	41.0	34.0	38.0	61.0	68.0	19.0	9.0	0	1.5	297.5
1964-65	4.4	6.4	45.2	80.8	75.3	34.8	92.8	49.6	39.0	16.5	0	0	444.8
1965-66	25.8	6.5	63.3	32.8	25.9	44.5	26.5	46.2	10.5	6.0	0	0	288.0
1966-67	1.0	27.5	34.5	35.2	58.0	63.5	43.5	45.5	37.5	15.5	0	0	361.7
1967-68	4.5	39.0	40.0	80.0	16.5	76.6	37.5	52.5	39.5	1.5	0	0.5	346.2
1968-69	22.0	15.0	55.5	28.5	50.5	33.0	31.5	39.0	53.0	24.0	0	0	352.0
1969-70	0	90.0	41.0	58.0	71.5	45.0	67.0	60.0	12.0	14.5	0	0	459.0
1970-71	34.5	47.0	78.5	47.0	34.8	55.0	55.5	67.5	25.5	0	0	0	445.3
1971-72	18.5	28.5	53.0	39.0	51.5	57.0	66.0	50.5	13.5	1.5	0	3.0	382.0
1972-73	6.0	16.0	57.5	34.0	32.0	28.0	49.5	74.5	54.0	15.0	0	0	366.5
1973-74	13.0	10.5	49.5	86.5	47.0	36.0	81.5	75.0	8.0	44.0	0	0	451.0
1974-75	14.5	25.5	53.5	38.5	56.0	36.5	50.0	43.5	38.5	18.0	0	0	374.5
1975-76	0	15.5	45.0	29.0	51.5	32.0	48.5	52.5	16.0	11.5	0	0	301.5
1976-77	13.0	20.5	29.0	26.5	30.0	35.0	48.0	42.0	20.5	0	0	0.3	264.8

1/ Winters without data: 1927-28; 1929-30; 1930-31; 1939-40 through 1948-49.

Maximum monthly snow depth (inches) at Berthoud Pass, Colorado, 1931-77

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1931-32	--	12	24	48	68	97	94	55
1932-33	--	25	43	54	78	106	[1] 174	130
1933-34	--	--	15	17	88	96	52	42
1934-35	--	24	52	65	70	83	118	110
1935-36	24	26	40	85	119	123	128	96
1936-37	6	19	38	47	72	80	86	58
1937-38	19	26	38	61	64	81	100	104
1938-39	2	23	53	70	82	96	109	--
1939-40	4	--	--	--	--	--	--	--
1940-42	--	--	--	--	--	--	--	--
1942-43	--	--	59	60	69	86	95	--
1943-44	--	25	34	43	56	68	94	--
1944-45	--	12	24	39	55	74	--	--
1945-46	10	26	56	60	75	76	--	--
1946-47	11	19	31	36	62	80	110	--
1947-48	16	30	34	62	66	84	94	--
1948-49	6	21	60	61	70	85	94	--
1949-50	14	14	22	43	57	74	82	--
1950-51	--	--	--	66	80	92	115	--
1951-52	--	24	72	74	87	94	101	--
1952-53	--	--	28	48	58	67	72	--
1953-54	--	--	38	37	44	60	56	--
1954-55	--	--	30	43	53	73	76	--
1955-56	--	28	48	64	74	70	83	--
1956-57	--	24	34	58	61	72	108	95
1957-58	--	24	46	55	71	86	95	--
1958-59	--	19	42	52	73	81	83	--
1959-60	--	36	40	54	73	93	87	--
1960-61	--	16	34	41	49	60	76	70
1961-62	26	33	44	64	77	79	90	72
1962-63	2	10	20	36	55	60	52	35
1963-64	6	10	31	32	47	67	72	64
1964-65	3	18	47	63	66	90	86	70
1965-66	6	24	27	31	46	47	52	41
1966-67	12	17	29	45	60	60	64	66
1967-68	18	24	48	47	74	72	74	65
1968-69	6	23	30	47	53	56	57	70
1969-70	27	35	54	66	73	84	93	83
1970-71	17	40	42	52	68	81	75	67
1971-72	12	29	36	40	59	74	69	59
1972-73	6	31	39	50	51	63	86	85
1973-74	6	20	56	58	62	80	93	77
1974-75	7	23	36	57	61	72	73	68
1975-76	10	21	26	44	48	62	62	55
1976-77	12	16	23	33	44	62	65	47

[1] Occurred on April 22, 1933

Monthly and seasonal precipitation (inches) at Berthoud Pass, Colorado 1949-77

Season	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Total
1949-50		2.45				2.08	3.56		2.64				
1950-51			4.35	3.09	1.99	3.32	1.09	6.77					
1951-52			2.43	7.27	3.19	3.16	3.42	5.08					
1952-53			1.71	3.50	5.98	3.49	3.83	3.50					
1953-54			3.80	3.04	1.13	2.45	4.73	1.61					
1954-55			2.70	2.09	2.67	2.28	5.40	2.28					
1955-56			4.50	3.77	5.62	4.06	2.10	5.13					
1956-57			2.35	2.99	6.07	3.07	5.61	9.89	5.10	1.24	0.47	3.98	
1957-58	1.72	2.30	1.87	4.17	2.67	4.77	5.85	4.86					
1958-59			1.75	4.59	3.59	4.32	4.11	2.71					
1959-60	3.24	2.97	2.06	0.88	2.20	4.51	4.63	2.45					
1960-61			1.50	2.75	1.42	2.15	3.76	5.33		1.70	4.85	3.76	
1961-62	5.32	1.65	2.26	3.71	3.91	3.67	2.00	4.62	2.24	2.30	0.96	0.92	33.56
1962-63	1.24	0.49	1.27	1.84	4.04	4.13	3.12	1.85	0.89	3.35	2.09	6.20	30.51
1963-64	2.82	0.97	1.31	2.66	2.25	2.67	4.47	4.03	1.69	1.87	2.70	1.19	28.63
1964-65	1.16	0.74	2.87	5.63	4.47	1.95	5.60	3.28	2.73	3.84	5.98	3.32	41.57
1965-66	3.06	0.76	3.94	1.65	1.42	2.65	1.62	3.41	1.60	2.46	2.62	2.54	27.73
1966-67	2.35	2.20	1.81	2.66	3.99	4.29	2.91	3.73	3.82	3.24	1.76	2.12	34.88
1967-68	2.31	2.99	2.72	4.45	1.24	5.12	2.70	4.02	4.05	0.45	1.88	3.13	35.06
1968-69	3.02	1.49	3.90	2.55	3.90	2.14	2.23	3.50	6.10	5.23	1.76	3.52	39.34
1969-70	2.36	6.84	2.77	3.88	4.80	2.81	4.45	4.28	1.21	2.25	2.40	2.39	40.44
1970-71	3.77	2.99	5.15	3.26	3.70	4.55	4.01	6.22	3.23	0.53	1.65	1.56	40.56
1971-72	2.09	2.25	3.30	2.75	4.78	4.03	4.85	4.08	1.89	3.26	1.02	2.78	37.08
1972-73	3.09	1.86	4.06	3.03	2.12	1.60	3.23	5.72	5.55	1.80	4.06	1.29	37.41
1973-74	2.03	0.98	3.54	6.79	3.56	2.64	6.14	6.43	0.59	4.31	2.94	1.18	41.13
1974-75	1.94	2.52	3.21	3.20	4.53	2.87	3.60	3.99	3.82	2.69	2.72	1.75	36.84
1975-76	1.72	1.35	3.63	1.96	3.82	2.67	3.74	4.17	2.50	1.62	2.36	3.52	33.06
1976-77	3.09	1.87	1.86	1.80	1.98	2.78	4.52	3.98	2.12	1.14	2.38	3.12	30.64

Q-12 Park—Elevation 11,314 Feet

Daily Precipitation

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. — YEAR 1963

DAILY PRECIPITATION - INCHES

DAY	JAN.	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.01	.55	.07	.00	.00	.00	.00	.00	.55	.00	.17	.00	1
2	.11	1.27	.26	.00	.24	.10	.13	.48	.03	.00	.00	.00	2
3	.01	.02	.17	.38	.03	.34	.00	.76	.00	.00	.00	.00	3
4	.2	.00	.27	.00	.00	.04	.07	.07	.00	.00	.31	.00	4
5	.07	.00	.07	.0	.00	.03	.0	.76	.00	.00	.31	.00	5
6	.0	.00	.08	.00	.00	.00	.14	.27	.03	.00	.07	.00	6
7	.00	.00	.03	.00	.00	.00	.00	.14	.93	.00	.00	.14	7
8	.00	.00	T	.00	.00	.00	.0	.48	.24	.00	T	.07	8
9	.	.00	.00	.10	.00	.55	.24	.18	.24	.00	.00	.00	9
10	.	.00	.0	T	.00	.11	.13	.00	.00	.00	.00	.45	10
11	.23	.10	.02	.01	.00	.06	.00	.10	.04	.00	.00	.03	11
12	.04	.00	.12	.00	.00	.00	.00	.34	.00	.00	.00	.14	12
13	.1	.00	.15	.00	.00	.00	.0	.25	.00	.00	.00	.14	13
14	.04	.00	.02	.00	.00	.00	.00	.07	.00	.00	T	T	14
15	.02	.10	T	.00	.00	.24	.21	.00	.03	.00	.00	.17	15
16	.02	.14	.47	.05	.00	1.24	.04	.00	.04	.00	.00	.07	16
17	.15	.06	.03	.00	.03	.04	.13	.10	.00	.00	.28	T	17
18	.22	.14	.14	.14	.00	.03	.00	.20	.03	.00	.00	T	18
19	.02	.12	.25	.14	.00	.34	.00	.00	.00	.00	.00	.00	19
20	.10	.30	T	.00	.07	.18	.00	.00	.07	T	.00	.00	20
21	.21	.43	.00	.00	.00	.00	.00	.00	.52	.48	.00	.17	21
22	.17	.03	T	.24	.00	.0	.00	.04	.00	.00	.15	.14	22
23	.1	.05	.0	.00	.31	.00	.58	.34	.00	.00	.00	.03	23
24	.	.15	.00	.00	.07	.00	.35	.31	.07	T	.00	.00	24
25	.33	.26	.10	.00	.04	.00	.1	.10	.00	.04	.10	.00	25
26	.7	.11	.0	.00	.03	.00	.0	.00	.00	.00	.00	.00	26
27	.0	.21	.0	.24	.00	.00	.0	.66	.00	.00	.00	.11	27
28	.0	.10	.0	.17	.00	.04	.0	.10	.00	.00	.00	.38	28
29	.1		.32	.35	.00	.00	.00	.24	.00	.00	.00	.52	29
30	.47		.00	.07	.07	.00	.0	.04	.00	.00	.00	.10	30
31	.5		.0		.00		.00	.17		.45		.00	31
TOT	4.00	4.14	2.57	1.84	.49	3.34	2.09	6.20	2.82	.97	1.39	2.66	TOT

TOTAL PRECIPITATION = 34.06 INCHES GREATEST 24 HOUR AMOUNT = 1.27 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 106, 0.50 = 14, 1.00 = 2

OBSERVATIONS ARE FROM THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.00	.00	.02	.00	.14	.13	.28	.24	.[illegible]	.00	.	.	1
2	.00	.20	.00	.28	.03	.52	.0[illegible]	.16	.00	.[illegible]0	.00	.[illegible]	
3	.31	.07	.41	.44	.33	.17	.0	.19	.00	.[illegible]	.31	.31	3
4	T	.03	.05	.11	.02	.24	.0[illegible]	.45	.00	.00	T	.03	4
5	.07	.00	.10	.12	.00	.02	.0[illegible]	.31	.00	.00	.00	.[illegible]	
6	.02	.18	.33	.37	.00	.02	.0[illegible]	.03	.[illegible]	.00	.[illegible]	T	6
7	.11	.07	.12	.65	T	.0[illegible]	.0[illegible]	.19	.[illegible]	.00	.00	.00	7
8	.19	.10	.25	.14	.15	.08	.0[illegible]	.07	.00	.00	.00	.00	8
9	T	.04	.00	T	.02	.12	.0[illegible]	.12	.03	.00	.00	T	9
10	.06	.13	.14	.00	.00	.00	.10	.00	.00	.[illegible]3	.02	.17	10
11	.21	T	.10	.08	.17	T	.07	.00	.00	.11	.[illegible]7	.[illegible]7	11
12	.1[illegible]	.04	.00	.29	.17	T	.0[illegible]	.00	.00	.0[illegible]	.[illegible]7	.[illegible]4	12
13	.00	.06	.10	.28	.00	.00	.0[illegible]	.12	.[illegible]0	.[illegible]0	.[illegible]4	.[illegible]	13
14	.00	.14	.13	.34	T	.07	.01	.00	.[illegible]4	.00	.34	.00	14
15	.0[illegible]	.11	.03	.00	.00	.04	.0	.00	.02	.0[illegible]	.45	.[illegible]3	15
16	T	T	.12	.00	.00	.00	.09	.00	.19	.00	.07	.[illegible]	16
17	.04	.10	.00	.00	.00	.00	.[illegible]2	.17	.00	.12	T	.[illegible]	17
18	.03	.36	.00	.00	.00	.10	.10	.30	.00	.[illegible]5	.[illegible]	.[illegible]6	18
19	.35	.18	.5[illegible]	.18	.00	.00	.00	.00	.[illegible]7	.[illegible]5	.11	.13	19
20	.14	.31	.23	T	.07	.00	.00	.14	.21	.00	.10	T	20
21	.0[illegible]	T	.00	.34	.00	.00	.0	.00	.00	.00	.[illegible]7	T	21
22	.06	.10	.00	.12	.00	.23	.0[illegible]	.00	.05	.00	.[illegible]	.13	22
23	.14	.14	.05	.00	.00	.03	.14	.00	.[illegible]0	.04	T	.[illegible]0	23
24	.07	.00	.28	.00	.00	.00	.4[illegible]	.07	.00	.17	.[illegible]4	1.23	24
25	.07	.17	.26	.20	.00	.00	.0[illegible]	.00	.00	.00	T	.[illegible]4	25
26	T	.04	.31	.07	.05	.00	.00	.00	.00	.00	.05	.[illegible]	26
27	.21	.10	.69	.40	.09	T	.0[illegible]	.21	.3[illegible]	.00	.[illegible]	.1[illegible]	27
28	.0[illegible]	T	.17	.18	.24	T	.0[illegible]	.08	.00	.00	.13	.63	28
29	.00	.00	.00	.04	.00	.01	.05	.12	.00	.00	.[illegible]3	.17	29
30	.00		.00	T	.17	.09	.0[illegible]	T	.00	.00	T	.[illegible]6	30
31	.07		.00		.04		.33	.00		.17		T	31
TOT	2.25	2.67	4.47	4.03	1.69	1.87	2.17	2.67	1.1[illegible]	.7[illegible]	2.87	5.[illegible]	TOT

TOTAL PRECIPITATION = 32.22 INCHES GREATEST 24 HOUR AMOUNT = 1.23 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 114, 0.50 = [illegible], 1.00 = 1

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.15	.65	.21	.00	.00	.03	.0	.41	.[illegible]	.[illegible]4	.[illegible]0	.[illegible]	1
2	.07	T	.07	.23	.00	.30	.0[illegible]	.43	.00	.[illegible]	.00	.[illegible]	
3	.00	.00	.01	.32	.00	.00	.0	T	.[illegible]4	.00	.00	.00	3
4	.0[illegible]	.00	.06	.06	.00	.00	.0[illegible]	.09	.1[illegible]	.[illegible]	.[illegible]	.[illegible]	4
5	.00	.00	.00	.58	.17	1.01	.0[illegible]	.[illegible]5	.[illegible]4	.00	.[illegible]	.[illegible]	
6	.0[illegible]	T	.00	.15	.03	.31	.1[illegible]	T	.[illegible]4	.[illegible]	.[illegible]	.[illegible]	6
7	T	.09	.00	.03	.00	.06	.0	.00	.[illegible]3	.[illegible]	.[illegible]0	.[illegible]	7
8	T	.12	.00	.11	.12	.04	.14	.00	.24	.[illegible]	.[illegible]	.[illegible]	8
9	.02	.06	T	.00	.30	.00	.1[illegible]	.00	.00	.[illegible]	.04	.[illegible]	9
10	.17	.17	.31	.17	.11	.45	.03	.07	.00	.[illegible]	.[illegible]3	.[illegible]3	10
11	.07	.04	.14	.40	.10	.[illegible]3	.0	.06	.[illegible]6	.[illegible]	.	.[illegible]	11
12	.59	.02	.03	.06	.00	.44	.24	.04	.11	.[illegible]	.[illegible]3	.[illegible]	12
13	.05	.01	.41	.04	.00	.31	.07	.00	.[illegible]6	.[illegible]	.[illegible]	.[illegible]	13
14	.19	.14	.24	.00	.19	.00	.0[illegible]	.14	.[illegible]3	.[illegible]	.[illegible]	.[illegible]3	14
15	.20	.17	.33	.02	.48	.00	.0	.00	.0[illegible]	.[illegible]3	.[illegible]	.[illegible]	15
16	.04	.04	.00	.00	T	.08	.0[illegible]	.24	.[illegible]	.[illegible]3	.[illegible]	.06	16
17	.00	.00	.36	.00	.00	.2[illegible]	.54	.10	.07	T	.1[illegible]	.04	17
18	.00	.00	.38	.36	.00	.05	.0[illegible]	.59	.03	.38	.[illegible]	.00	18
19	.00	.00	T	.17	.00	.0[illegible]	.2	.55	.[illegible]2	.1[illegible]	.[illegible]	.00	19
20	.00	.00	.14	.00	.09	.[illegible]0	.00	.59	.43	.14	T	T	20
21	.00	.00	.10	.00	.00	.[illegible]0	.14	.00	.[illegible]7	.[illegible]	.[illegible]4	.[illegible]	21
22	.18	.00	.17	.00	.03	.0[illegible]	.55	[illegible]	.[illegible]4	.[illegible]	.[illegible]3	.[illegible]	22
23	.1[illegible]	.34	.55	.00	.00	.00	1.19	.[illegible]	.[illegible]4	.[illegible]0	.[illegible]	[illegible]	23
24	.04	.07	.62	T	.28	.00	.67	.03	.[illegible]4	.[illegible]0	.[illegible]1	.[illegible]3	24
25	.37	T	.38	.03	T	.0[illegible]	.45	.[illegible]0	.[illegible]3	.[illegible]	.[illegible]4	.[illegible]	25
26	.03	.00	.08	.16	.21	.05	.[illegible]7	.[illegible]0	.07	.[illegible]	.[illegible]	T	26
27	.17	.00	.54	.39	.41	.02	.0	.00	.[illegible]3	.[illegible]3	.[illegible]3	.[illegible]	27
28	.34	.03	.24	T	.21	.00	.37	.00	.[illegible]6	.[illegible]7	.14	.[illegible]	28
29	.34		.17	.00	.00	.00	.0[illegible]	.00	.[illegible]9	.[illegible]6	.[illegible]6	.00	29
30	1.03		.06	.00	.00	.00	.0[illegible]	.03	.[illegible]5	.[illegible]0	.[illegible]0	.17	30
31	.28		.00		.00		.[illegible]6	.00		.[illegible]1		.[illegible]0	31
TOT	4.47	1.95	5.60	3.28	2.73	3.84	5.[illegible]	3.32	3.[illegible]	.7[illegible]	3.94	1.65	TOT

TOTAL PRECIPITATION = 40.58 INCHES GREATEST 24 HOUR AMOUNT = 1.19 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 116, 0.50 = 20, 1.00 = 3

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1966

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.05	.44	.00	.00	.00	.52	.14	.07	.24	T	.36	.00	1
2	.07	.14	T	T	.00	.00	.00	.07	.79	.00	.00	.00	2
3	.00	.07	.05	.24	.00	.00	.00	.28	.00	.54	.00	.00	3
4	.00	.00	.05	.34	.00	.00	.00	.82	.06	.39	T	.07	4
5	.00	.00	.00	.23	.00	T	.00	.17	.00	.00	.03	T	5
6	.00	.00	.00	.04	.00	.00	.00	.04	.00	.00	.00	1.03	6
7	T	.04	.00	.00	.00	.00	.00	.00	.08	T	.00	.79	7
8	.00	.15	.00	.00	.00	.57	.00	.00	.02	.00	T	.11	8
9	T	.33	.05	.03	.07	.05	.00	.00	.00	.00	.69	.14	9
10	.00	.14	.00	.00	.55	.25	.03	.03	.00	.00	.18	.00	10
11	.00	.06	.35	.34	.13	.03	.04	.00	.00	.00	.08	.08	11
12	.31	.02	.00	.50	.28	.03	.27	.00	.12	.04	.04	.04	12
13	.09	.25	.00	.02	.23	.00	.11	.22	T	.02	.01	.00	13
14	.03	.11	.00	.08	.01	.00	.10	.00	.10	.98	.00	.00	14
15	.29	.12	.00	.00	.00	.00	.00	.03	.41	.04	.00	.05	15
16	.12	.19	.00	.00	.00	.16	.00	.00	.04	.00	.00	.00	16
17	.00	.11	.33	T	.00	.13	.00	.02	.03	.14	.00	.00	17
18	.00	.03	.24	.35	.00	.17	.45	.00	.00	T	T	.00	18
19	.00	.00	.00	.22	.00	.05	.47	.00	.00	T	.00	.00	19
20	T	.02	.00	.22	.00	.02	.25	.54	.00	.00	.00	.00	20
21	.13	.10	.05	T	.00	.05	.00	.04	.02	.00	.00	.00	21
22	.05	.02	.40	.06	.02	.27	.17	.00	.00	.00	.00	.03	22
23	T	T	.10	.45	.15	.02	.00	.00	.00	T	.00	.04	23
24	.12	.00	.00	.00	.00	.07	.14	.00	.00	.05	.00	.00	24
25	.12	.00	.00	.00	.00	.00	.14	.00	.23	.00	.00	.00	25
26	T	.07	.01	.00	.00	.00	.07	.00	.03	.00	.17	.00	26
27	.00	.07	.00	.27	.02	.07	.17	.00	.04	.00	.11	T	27
28	.00	.17	.00	.02	.10	.00	.07	.00	.00	.00	.00	.15	28
29	T		.00	.00	.02	.00	.00	.00	.00	.00	T	.05	29
30	.00		.00	.00	.02	.00	.00	.00	.10	.00	.14	.03	30
31	.04		.00		.00		.01	.21		T		.05	31
TOT	1.42	2.65	1.62	3.41	1.60	2.46	2.62	2.54	2.35	2.20	1.81	2.66	TOT

TOTAL PRECIPITATION = 27.34 INCHES GREATEST 24 HOUR AMOUNT = 1.03 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 85, 0.50 = 12, 1.00 = 1

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1967

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.07	.35	.00	.00	.60	.24	.03	.05	.07	.00	.00	.04	1
2	.21	T	.00	.00	.02	.00	.00	.00	.00	.00	.81	.42	2
3	.07	.00	.00	.00	.36	.00	.00	.00	.02	.04	.28	.00	3
4	.31	.00	.00	.00	T	.00	.07	.33	.00	.00	.00	.00	4
5	T	.00	.18	.00	.07	.13	.33	.00	.00	.79	.00	.00	5
6	.14	.10	.05	.24	.71	.00	.00	.00	.00	.02	.00	.15	6
7	T	.24	.21	.00	.07	.09	.03	.17	T	.19	.00	.00	7
8	.20	.04	.05	.00	.00	.00	.00	.12	.00	.00	.00	.21	8
9	.01	.00	.03	.00	.00	T	.00	.00	.07	.00	.00	.24	9
10	T	.17	.00	.38	.00	.00	.00	.38	.07	T	.10	.07	10
11	.00	.42	.00	.00	.03	.65	.00	.00	.98	.00	.05	.08	11
12	T	.06	.00	.00	.04	.19	.28	.00	.00	.00	.00	.14	12
13	.17	.00	.00	.34	T	.16	.07	.01	.02	.00	.00	.06	13
14	.59	.04	.00	1.27	.33	.02	.00	.06	.00	.00	.00	.04	14
15	.31	.78	.27	.00	.08	.10	.00	.08	.00	.23	.00	.00	15
16	.27	.11	.00	.03	.04	.44	.47	.03	.07	.03	.00	.00	16
17	.48	.06	.04	.42	.00	.12	.00	.00	.10	.00	.00	.24	17
18	.02	.52	.65	.00	.00	.09	.19	.00	.07	.00	.00	.03	18
19	.00	.21	.23	.00	.05	.00	.00	.02	.38	.00	.00	.14	19
20	.00	.32	.30	.07	.31	.07	.00	.00	.00	.00	.05	.29	20
21	.00	.00	.08	.05	.00	.28	.00	.00	.00	.00	.19	.27	21
22	.00	.14	.00	.00	.00	.10	.00	.00	.00	.00	.56	.07	22
23	.00	.19	.00	.26	.00	.21	.10	.00	.00	.00	.20	.11	23
24	.12	.35	.00	.00	.00	.00	.10	.00	.00	.48	.31	.00	24
25	.10	.00	.13	.07	.00	.02	.02	.00	.00	.00	.17	.24	25
26	.59	.17	.26	.14	.34	.00	.03	.07	.17	.31	.00	.28	26
27	.19	.02	.03	.00	.30	.11	.00	.00	.00	.29	.09	.00	27
28	T	.00	.16	.00	.21	.03	.07	.17	.00	.00	.00	.23	28
29	.00		.00	.00	.19	.19	.00	.15	.00	.79	.00	.07	29
30	.05		.17	.46	.00	.00	.00	.24	.00	.02	T	.30	30
31	.10		.07		.07		.00	.24		.00		.18	31
TOT	3.94	4.29	2.91	3.73	3.82	3.24	1.76	2.12	2.31	2.99	2.72	4.45	TOT

TOTAL PRECIPITATION = 38.33 INCHES GREATEST 24 HOUR AMOUNT = 1.27 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 117, 0.50 = 15, 1.00 = 1

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1968

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.05	.34	.01	.00	.00	.00	.00	.09	.00	T	.04	.03	1
2	.15	T	.00	.26	.00	.00	.00	T	.00	.12	.03	.11	2
3	.41	.07	.08	.65	T	.00	.00	.01	.61	T	.00	.07	3
4	.07	.12	.00	.22	.00	.00	.00	.10	.65	.00	T	.05	4
5	.00	T	.00	.06	T	.04	.14	.00	T	.37	.25	.00	5
6	.07	.00	.00	T	T	.00	.31	.38	.00	T	.07	.00	6
7	.00	.00	.00	.16	.24	.00	.00	.05	.00	.00	.14	.00	7
8	.00	.00	.17	.23	.04	.07	.00	.09	T	T	.00	.00	8
9	.00	.01	.31	T	T	.02	.04	.24	.00	.48	.12	.00	9
10	.00	.00	.07	.00	.31	.03	.12	.48	.00	.00	.95	.00	10
11	.15	.00	.11	.00	.34	.17	T	.14	.00	.00	.02	.00	11
12	.10	.17	.01	.00	T	.00	.24	.07	.00	.00	.00	.24	12
13	.00	.05	.00	.02	.11	.00	T	T	.34	.00	T	.24	13
14	.00	.03	.61	.22	.05	.00	T	.11	T	.00	.13	.00	14
15	.00	.25	.51	.00	.50	T	.00	.41	.14	.00	.16	.00	15
16	.00	.07	T	.02	.06	.00	.27	.00	.59	.17	.11	.00	16
17	.00	.09	.01	.03	.29	.00	.00	.03	.38	.30	.75	.05	17
18	.05	.27	.11	.30	.16	.00	.01	.00	T	.02	.11	.38	18
19	.00	.21	.03	.10	.03	.00	.00	.00	.00	.00	.13	.07	19
20	.00	.10	.10	.50	.17	.00	.02	.00	.00	.00	T	.00	20
21	.00	.65	.25	.00	.30	.00	.00	.02	.00	.00	.00	.20	21
22	.03	.30	.16	.31	.00	.00	.00	.12	.00	T	.00	.21	22
23	.06	.70	T	.10	.00	.00	.18	.11	.07	.00	.16	.03	23
24	.00	.60	.00	.00	.05	.00	.08	.00	.00	.00	.06	.00	24
25	.00	.21	.00	.14	.41	.12	.02	.00	.00	.00	.15	.00	25
26	.00	.00	.02	.40	.41	.00	T	T	.00	.00	.21	.07	26
27	.00	.13	.11	.20	.35	.00	.03	.02	.00	.00	.00	.11	27
28	.10	.60	.00	.10	.03	.00	.00	.46	.00	.00	.17	T	28
29	.00	.15	.00	.00	.00	.00	.11	.14	.24	.00	.14	.05	29
30	.00		.00	.00	.00	.00	.13	.06	.00	.00	.00	.19	30
31	.00		.03		.20		.18	.00		.03		.45	31
TOT	1.24	5.12	2.70	4.02	4.05	.45	1.88	3.13	3.02	1.49	3.90	2.55	TOT

TOTAL PRECIPITATION = 33.55 INCHES GREATEST 24 HOUR AMOUNT = .95 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 116, 0.50 = 14, 1.00 = 0

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1969

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	T	.00	.00	.03	.00	.21	.00	.00	.02	.17	.46	.00	1
2	.00	.34	.35	.40	.00	.00	.00	.00	.00	.00	.60	.00	2
3	.10	.04	.04	.00	.03	.05	.00	.00	.00	.52	.05	.00	3
4	T	.00	T	.29	T	T	T	.22	T	1.20	.02	.00	4
5	.17	.00	.07	.02	.55	.00	.21	.00	.10	1.15	.00	.15	5
6	.18	.07	.05	.00	.22	.00	.04	.00	T	.02	.00	.21	6
7	T	.01	.27	.30	3.06	.30	.00	.00	.00	.01	.00	.02	7
8	.26	.13	T	.14	1.09	.07	.00	.00	.11	.00	.09	.04	8
9	.43	.00	T	.03	.00	.20	.08	.00	.04	.00	.00	T	9
10	.00	.00	.23	T	.00	.02	.00	.00	.42	.22	.03	.22	10
11	.00	.00	T	.00	.00	.33	.00	.00	.25	.70	.04	.18	11
12	.12	.00	T	.05	T	.65	.00	.33	.00	.65	.10	.05	12
13	.02	.00	.07	.47	.04	.05	.00	.34	.26	.17	.76	.00	13
14	.00	.21	.10	T	.00	.24	.03	.00	.00	.00	.14	.00	14
15	.10	T	.00	.21	T	.21	.28	T	.00	.30	.00	.00	15
16	T	.10	.00	.52	.66	.66	.00	.00	.33	.07	.00	.00	16
17	.14	.52	.00	.15	.31	.14	.00	.07	.37	.15	.22	.00	17
18	.07	.05	.00	T	.00	.51	.00	.35	.23	T	.20	.00	18
19	.00	T	.40	.00	.02	.07	.02	.38	.00	.23	.01	.00	19
20	T	.15	T	.00	.00	T	.46	T	.00	.00	.00	.14	20
21	.03	.26	.00	.00	.00	.02	.09	.82	.06	.00	.00	.17	21
22	.12	.03	.00	.00	T	.00	.00	.33	.10	.00	.00	.34	22
23	.38	T	.17	.04	.03	.20	.00	.00	.07	.10	.00	.16	23
24	.15	.00	.25	.00	.04	.40	.00	.00	.00	T	.00	.43	24
25	.25	T	.12	.26	.00	.46	.00	.00	.00	.00	.00	.67	25
26	.58	.00	.05	.32	.00	.25	.00	.00	.00	.00	.00	.34	26
27	.49	.23	.02	.27	.00	.19	.00	.00	.00	.00	.05	.49	27
28	.25	T	.00	T	.00	.00	.00	T	.00	.00	.00	.12	28
29	.02		.04	.00	T	.00	.00	.13	.00	.35	.00	.02	29
30	.04		.00	.00	.00	.00	.51	.55	.00	.67	.00	.03	30
31	.00		.00		.05		.04	T		.14		.10	31
TOT	3.90	2.14	2.23	3.50	6.10	5.23	1.76	3.52	2.36	6.84	2.77	3.88	TOT

TOTAL PRECIPITATION = 44.23 INCHES GREATEST 24 HOUR AMOUNT = 3.06 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 121, 0.50 = 22, 1.00 = 4

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

YEAR 1970

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.14	.05	T	.07	.24	.12	.00	.00	.00	.00	.17	T	1
2	.00	[illegible]	.07	.06	.05	T	.00	.00	.10	.00	.10	.00	2
3	T	[illegible]	[illegible]	.34	.00	[illegible]	.00	.00	.04	.00	.09	.22	3
4	[illegible]	.60	.05	[illegible]	.00	T	.00	.10	.00	.00	T	.00	4
5	[illegible]	T	.02	[illegible]	.00	.04	.38	.05	.05	.00	.00	.05	5
6	T	.02	.21	.00	.00	.00	.11	.09	.25	.00	.04	.00	6
7	.05	T	T	.00	T	.00	.00	.29	.15	.05	.00	.00	7
8	T	T	.00	.02	.00	.08	.22	.24	.00	.15	.78	.00	8
9	T	.00	.05	.00	.17	T	.23	.00	.00	.08	.12	.00	9
10	.14	.00	.15	.00	.25	.12	.13	.00	.00	.60	.00	.17	10
11	.2	.00	.04	T	.00	.62	.00	.00	.00	.62	.42	.38	11
12	.05	.07	.15	.32	.00	.93	.28	.00	.09	.00	T	.12	12
13	.05	.25	.10	.14	.00	.07	.14	.00	.51	.00	.38	.00	13
14	.01	.33	.44	.09	.02	.00	.00	.00	.05	.00	.21	.00	14
15	T	.05	.09	.12	.13	.00	.04	.06	.05	.32	T	.12	15
16	.00	T	.31	.03	.00	.00	.00	.00	.08	.00	.00	.07	16
17	.45	.00	.03	.07	.00	.00	.00	.00	.00	.00	.11	.00	17
18	.42	.39	.49	.45	.00	.02	.02	.00	.00	.00	.13	.24	18
19	.07	.03	.21	.14	.00	.00	.23	.00	.00	.00	.50	.26	19
20	.45	.00	.00	.79	.00	.00	.00	.05	.00	.00	.04	.02	20
21	.35	.00	.03	.06	.00	.05	.04	.75	.00	.20	.00	.17	21
22	.17	.00	.25	.62	.02	T	.05	.32	1.29	.07	.18	.12	22
23	.24	.00	.04	T	.02	.00	.10	.02	.00	.35	.96	.31	23
24	.0	.07	.00	.07	.00	T	.00	.00	.00	T	T	.10	24
25	.48	.38	.89	.00	T	.00	.00	.00	1.06	.15	.06	.18	25
26	.05	.09	T	.00	T	.00	.04	.00	.05	.12	.12	.00	26
27	.05	.00	.21	.00	T	.00	.24	.00	.00	.28	.54	.09	27
28	.5-	.00	.00	.16	T	.01	.00	.13	.00	.00	.02	.09	28
29	.2-		.12	.12	.14	T	.00	.00	.00	.00	.00	.16	29
30	T		.16	.12	.10	.19	.00	.00	.00	.00	.00	.32	30
31	.00		.03		.37		.10	.29		.00		.07	31
TOT	4.80	2.81	4.45	4.27	1.21	2.25	2.47	2.39	3.77	2.99	5.15	3.26	TOT

TOTAL PRECIPITATION = 39.76 INCHES GREATEST 24 HOUR AMOUNT = 1.29 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 119, 0.50 = 18, 1.00 = 2

[illegible] ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

YEAR 1971

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	-	[illegible]	.11	.58	.00	.00	.0	.00	.00	.00	.15	.03	1
2	.24	T	.02	.00	.00	.00	.0	.00	.00	.55	.09	.00	2
3	.02	[illegible]	[illegible]	[illegible]	.00	.00	.00	.12	.06	.09	.13	.04	3
4	.01	.61	[illegible]	.24	.00	.04	.00	.00	.25	.00	.00	.07	4
5	[illegible]	.38	.49	.00	.14	.00	.00	.03	.35	.00	.00	.07	5
6	.01	.27	.16	.00	.03	.00	.00	.00	.00	.00	.09	.14	6
7	T	.07	.02	.00	.00	.00	.00	.00	.00	.00	.00	.21	7
8	.17	.19	.00	.10	.06	.00	.05	.00	.43	.00	.00	.03	8
9	[illegible]	.07	.25	.00	.11	.04	.42	.00	.03	.00	.05	T	9
10	.42	T	.00	.00	.52	.10	.09	.15	.00	.00	.00	.24	10
11	.0	.05	.10	.00	.16	.00	.00	.00	.00	.00	.00	.14	11
12	[illegible]	.15	[illegible]	.00	.06	.00	.00	.00	.00	.00	.00	.07	12
13	.04	T	.00	.00	.00	.00	.00	.07	.00	.00	.17	.14	13
14	.31	.08	.42	.00	.00	.00	.00	.15	.00	.00	.03	.15	14
15	.21	.00	.10	.00	.23	.00	.00	.00	.00	.00	.00	.16	15
16	.0	.17	.5-	.14	.14	.00	.00	.00	.00	.00	.09	.05	16
17	.17	.02	.00	.00	.08	.00	.00	.00	.50	.00	.02	.04	17
18	[illegible]	.06	.19	.00	.46	.00	.00	.00	.19	.34	.22	.00	18
19	.36	.70	.00	.07	.31	.33	.13	.07	T	.12	.12	.00	19
20	T	.29	.00	1.08	.04	.00	.27	.05	.00	.00	.03	.00	20
21	.31	.17	.00	.64	.00	.00	.00	.00	T	.00	.00	.00	21
22	T	.07	.23	.42	.00	.02	.38	.00	.21	.14	.47	.00	22
23	.08	[illegible]	.15	.24	.04	.00	.03	.00	.00	.00	.22	.15	23
24	[illegible]	T	.54	.23	.30	.00	.23	.10	.00	.00	.00	.02	24
25	[illegible]	[illegible]	.35	.00	.00	.00	.00	.00	.00	.00	.00	T	25
26	.02	.31	.07	.05	.00	.00	.05	.00	.00	.46	.27	T	26
27	.07	.17	.00	.56	.00	.00	.00	.24	.00	.00	.34	.75	27
28	.0-	.00	.31	.05	.00	.00	.00	.21	.00	T	.51	.04	28
29	.1		.00	.09	.31	.00	.00	.15	.00	.14	.19	.04	29
30	.0		.00	.05	.14	.00	.00	.22	.07	.37	.11	.10	30
31	.5		.7		.10		.00	.00		.04		.07	31
TOT	[illegible]	[illegible]	[illegible]	[illegible]	3.23	.51	1.65	1.56	2.09	2.25	3.30	2.75	TOT

TOTAL PRECIPITATION = 35.84 INCHES GREATEST 24 HOUR AMOUNT = 1.08 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 108, 0.50 = 17, 1.00 = 2

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 19[illegible]

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.00	.00	.25	.26	.00	.00	.00	.07	.52	.00	.47	T	1
2	.09	.16	.05	T	.00	.00	.00	.00	.32	.00	.2[illegible]	.[illegible]	2
3	.36	T	.46	.30	.00	.06	.00	.30	.05	.00	.[illegible]7	.[illegible]	3
4	T	.00	1.10	.00	.00	.06	.00	.00	.23	.00	.[illegible]	T	4
5	.10	.00	.86	.08	.00	.38	.00	.00	.03	.00	T	.66	5
6	.07	.08	.00	.00	.23	.55	.00	.00	.04	.00	.14	.10	6
7	.00	.15	T	.21	.04	.23	.15	.00	.18	.00	.06	.03	7
8	.00	.15	.00	.00	.39	.00	.00	.00	.04	.26	.00	.04	8
9	.14	T	.00	.00	.00	.60	.00	.10	.00	.04	.30	.24	9
10	.03	.28	.00	.00	T	.04	.00	.00	.28	.02	.07	.15	10
11	.86	.02	.00	.00	.14	.00	.00	.00	.20	.00	.00	.00	11
12	.18	.04	.00	.32	.14	.00	.00	.00	.15	.00	.03	.06	12
13	1.13	T	.00	.12	.36	.12	.00	.00	.00	T	.21	.10	13
14	.13	.29	.00	.21	.26	.06	.00	.00	.00	.02	T	.07	14
15	.02	.23	.26	.12	.00	.00	.00	.22	.00	.00	.00	.00	15
16	.00	.35	.03	.04	.00	.26	.00	.14	.00	.19	.19	.00	16
17	.00	.75	.00	.00	.00	.03	.00	.52	.00	.00	.01	.00	17
18	.00	.38	.00	.00	.00	.00	.06	.00	.00	.17	.00	.00	18
19	.00	.00	.12	.00	.08	.15	.05	.27	.00	.02	.10	.07	19
20	.11	.00	.10	.00	.12	.35	.00	.20	.40	.00	.02	.24	20
21	.03	.00	.04	.12	.00	.15	.28	.00	.05	.45	.02	.07	21
22	.14	.00	.00	.16	.00	.00	.06	.00	.00	.21	.01	.05	22
23	.26	.14	.00	.00	.08	.00	.00	.00	.07	.08	.00	.24	23
24	.29	.15	.38	.00	T	.14	.00	.42	.00	.00	.00	.17	24
25	.02	.45	.03	.00	.00	.00	.01	.07	.00	.[illegible]	.18	.04	25
26	.05	.30	.00	.70	.00	.00	.00	.04	.00	.00	.18	.02	26
27	.21	.11	.24	1.10	.00	.00	.48	.00	.00	.00	1.31	.00	27
28	.14	.00	.31	.30	.05	.00	.00	.03	.20	.24	.23	.00	28
29	.42	.00	.12	.00	.00	.00	.00	.37	.29	.04	.14	.12	29
30	.00		.20	.04	.00	.08	.00	.00	T	.07	.07	.57	30
31	.00		.28		.00		.00	.03		.03		.07	31
TOT	4.78	4.03	4.85	4.08	1.89	3.26	1.02	2.78	3.09	1.86	4.06	3.03	TOT

TOTAL PRECIPITATION = 38.73 INCHES GREATEST 24 HOUR AMOUNT = 1.31 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 119, 0.50 = 14, 1.00 = 4

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1973

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.03	.17	.21	.04	.60	.00	.00	.00	T	.00	.24	.00	1
2	.00	.07	T	.21	.45	.16	.00	.07	.20	.00	.85	.00	2
3	.00	.00	.34	.28	.03	.18	.00	.04	.17	.00	.14	.[illegible]	3
4	.04	.02	.08	T	.00	.45	.00	.00	.00	.08	.61	.10	4
5	.17	.37	.04	.00	.00	.28	.00	.25	.00	.00	T	.11	5
6	.04	.03	.25	.00	.84	.00	.00	.20	.00	.00	.00	T	6
7	.03	.04	.07	.65	1.52	.00	.00	.00	.00	.00	T	.05	7
8	.03	.10	.00	.21	.10	.00	.04	.00	.00	.00	.00	.05	8
9	T	.00	.03	.17	.38	.00	.25	.00	.00	.00	.00	.02	9
10	.23	T	.28	.07	.00	.00	.00	.00	.10	.24	.00	.00	10
11	.11	.14	.00	.31	.00	.00	.00	.03	.08	.08	.00	.00	11
12	T	.00	.00	T	.00	.00	.00	.04	.08	.04	.00	.05	12
13	.14	.14	.00	T	.00	.00	.25	.00	.00	.05	.00	.10	13
14	T	.03	.45	.00	.00	.13	.67	.00	.00	.00	T	.52	14
15	.01	.10	.16	.56	.00	.10	.23	.00	.00	.00	.36	.18	15
16	.00	.00	T	.07	.00	.34	.52	.00	.00	.00	.00	.07	16
17	.00	.00	.00	.00	.00	.00	.08	.00	.12	.00	.00	.00	17
18	.13	.00	.00	.02	.00	.16	.00	.19	.03	.00	.00	.35	18
19	.01	.14	.49	.87	.00	.00	.63	.00	.00	.00	T	.14	19
20	.17	.00	T	.55	.38	.00	.27	.00	.00	.00	.40	.00	20
21	.68	.00	.00	.10	.04	.00	.05	.00	.00	.00	T	.00	21
22	.04	.00	.39	.33	.16	.00	.00	.27	.00	.00	.24	.00	22
23	.00	.00	.00	T	.20	.00	.00	.10	.00	.00	.08	.07	23
24	.00	.07	.12	T	.00	.00	.04	.03	.13	T	.12	.82	24
25	.00	.10	.22	.64	.31	.00	.08	.02	.03	.00	T	.03	25
26	.00	.08	.00	.60	.21	.00	.00	.00	.27	.00	.10	.26	26
27	.20	.00	.00	.02	.14	.00	.00	.00	.08	.00	.31	.07	27
28	.07	.00	.04	.00	.01	.00	.05	.00	.14	.00	.07	.54	28
29	.00		.03	.02	T	.00	.25	.00	.52	.00	.[illegible]	.[illegible]	29
30	.00		.00	.00	.18	.00	.65	.00	.08	.35	.00	1.58	30
31	.00		.03		.00		.00	.05		.14		.30	31
TOT	2.12	1.60	3.23	5.72	5.55	1.80	4.06	1.29	2.03	.98	3.54	6.79	TOT

TOTAL PRECIPITATION = 38.71 INCHES GREATEST 24 HOUR AMOUNT = 1.58 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 109, 0.50 = 22, 1.00 = 2

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1974

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	T	.15	.00	.16	.00	.00	.00	.00	.00	.00	.35	.00	1
2	.03	.40	.00	.11	.00	.00	.00	.00	.42	.00	.14	.00	2
3	T	.11	.73	1.13	.32	.02	.02	.05	.00	.00	.12	.00	3
4	.01	.04	.28	.20	.00	.00	.00	.00	.00	.29	.15	.00	4
5	T	T	T	T	.00	.00	.07	.05	.00	.02	.03	T	5
6	.24	.54	.00	.00	.00	.64	.00	.06	.08	.35	.00	.21	6
7	.28	.08	.00	.32	.00	.92	.20	.03	.00	.00	.00	.14	7
8	.28	.07	.00	.15	.00	1.36	.15	.25	.00	.00	.00	.06	8
9	.21	.08	.00	.00	.00	1.24	.00	.28	.00	.00	.04	.00	9
10	.24	.00	.04	.03	.00	.00	.00	.10	.00	.00	.18	.00	10
11	.10	.00	.65	.20	.04	.00	.07	.05	.00	.00	.50	.00	11
12	.00	.00	.06	.65	.00	.00	.00	.00	.60	.40	.00	.02	12
13	.24	.00	.00	1.32	.00	.00	.05	.00	.00	.14	.03	T	13
14	.12	T	.08	.17	.15	.00	.15	.00	.00	.14	.50	.24	14
15	.01	.00	.68	.02	.08	.00	.10	.00	.30	.00	.01	.18	15
16	.00	.00	T	.00	.00	.04	.10	.00	.18	.00	.05	.14	16
17	.00	.00	.00	.00	.00	.00	.32	.00	.08	.00	.00	.20	17
18	.50	.24	.00	.00	.00	.07	.00	.00	.00	.00	T	.20	18
19	.06	.04	.72	.00	.00	.00	.06	.00	.00	.00	.36	.38	19
20	.16	.45	.03	.07	.00	.00	.00	.18	.00	.00	.08	.27	20
21	.32	.16	.04	.34	.00	.00	.37	.00	.00	.00	.00	.50	21
22	.38	.00	.00	.28	.00	.00	.52	.00	.00	.14	.00	.22	22
23	.04	.28	1.12	.00	.00	.00	.32	.00	.00	.00	.15	.24	23
24	.04	T	.30	.00	.00	.00	.20	.00	.00	.36	.20	.06	24
25	.00	.00	.14	.00	.00	.00	.00	.00	.00	.20	.00	.00	25
26	T	.00	.00	.06	.00	.00	.00	.00	.00	.04	.18	.02	26
27	.16	.00	.00	.00	.00	.02	.08	.05	.00	.00	.05	.00	27
28	.08	.00	.06	.00	.00	.00	.04	.08	.28	.00	.05	.00	28
29	.14		.80	.92	.00	.00	.02	.00	.00	.02	.04	.00	29
30	.00		.12	.30	.00	.00	.10	.00	.00	.28	.00	.08	30
31	.00		.35		.00		.00	.00		.14		.04	31
TOT	3.56	2.64	6.14	6.43	.59	4.31	2.94	1.18	1.94	2.52	3.21	3.20	TOT

TOTAL PRECIPITATION = 38.66 INCHES GREATEST 24 HOUR AMOUNT = 1.36 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 106, 0.50 = 21, 1.00 = 5

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1975

DAILY PRECIPITATION - INCHES

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	DAY
1	.00	.00	.04	.08	.04	.08	.00	.36	.00	.00	.02	.08	1
2	.04	.00	.00	.20	.03	.00	.00	.00	.00	.00	.00	.08	2
3	.12	.00	.28	T	.04	.02	.00	.00	.00	.00	.00	.00	3
4	.00	.00	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	4
5	.18	.32	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5
6	.22	.20	.04	.00	.48	.00	.00	.04	.00	.00	.00	.00	6
7	.20	.02	.30	.00	.04	.00	.08	.00	.00	.00	.00	.00	7
8	.30	.18	T	.60	.08	.46	.04	.00	.00	.28	.18	.12	8
9	.16	.12	.14	.04	.02	.32	.28	.00	.00	T	.67	.04	9
10	.12	.14	.20	.06	.00	1.15	.00	.00	.76	.00	T	.00	10
11	.08	.72	.04	.24	.00	.02	.24	.00	.04	.00	.40	.00	11
12	.12	.00	.22	.02	.02	.00	.00	.04	.28	.00	.06	T	12
13	.16	.00	.02	.04	.80	T	.00	.28	.12	T	.00	.00	13
14	.02	.06	.02	.00	T	.00	.00	.36	.08	.04	.00	.18	14
15	.00	.20	.12	.00	.00	.00	.36	.04	.12	.06	.00	.16	15
16	.00	T	.04	.00	.00	.18	.52	.04	.04	.00	.00	.00	16
17	.13	.08	.02	.00	.00	.32	.48	.04	.24	.00	.00	.10	17
18	.04	.15	.04	.66	.04	.00	.00	.00	.04	.00	.00	.08	18
19	.27	.04	.02	.43	.36	.06	.04	.00	.00	.00	.16	.00	19
20	.00	.10	.00	T	.00	.08	.00	.00	.00	.00	.22	.00	20
21	.32	.32	.38	.04	.02	.00	.24	.07	.00	.00	.00	.00	21
22	.03	.08	.18	.00	.16	.00	.00	.42	.00	.00	.00	T	22
23	.02	.00	.24	.00	.78	.00	.00	.02	.00	.10	T	.00	23
24	.22	.02	.20	.00	.10	.00	.04	.00	.00	.77	.22	.04	24
25	1.24	.00	.20	.00	.02	.00	.02	.00	.00	.04	.70	.12	25
26	.10	.00	.04	.00	T	.00	.02	.00	.00	.00	.14	.10	26
27	.00	.00	.62	T	.00	.00	.04	.04	.00	.00	.46	.30	27
28	.14	.12	.04	1.30	.18	.00	.00	.00	.00	.00	.08	.40	28
29	.22		.02	.18	.39	.00	.12	.00	.00	.00	.14	.04	29
30	.00		.02	.10	.10	.00	.16	.00	.00	.00	.18	.04	30
31	.08		.04		.12		.04	.00		.06		.08	31
TOT	4.53	2.87	3.60	3.99	3.82	2.69	2.72	1.75	1.72	1.35	3.63	1.96	TOT

TOTAL PRECIPITATION = 34.63 INCHES GREATEST 24 HOUR AMOUNT = 1.30 INCHES
NUMBER OF DAYS PRECIPITATION EQUAL TO OR GREATER THAN 0.10 = 102, 0.50 = 14, 1.00 = 3

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1963

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	19	08	32	17	20	01	43	24	43	28	52	34	70	45	69	51	52	33	61	32	25	04	26	04	1
2	30	12	25	13	17	03	28	06	42	22	54	32	65	43	68	40	48	33	59	33	32	12	24	07	2
3	30	12	33	20	10	-04	25	07	42	28	42	39	67	45	58	39	55	40	58	32	45	15	29	13	3
4	17	07	36	20	05	-06	34	16	49	31	50	34	62	40	57	41	56	38	56	35	39	19	32	10	4
5	26	06	40	19	09	-07	33	19	51	31	55	27	63	39	53	41	63	42	56	33	31	17	26	11	5
6	15	00	40	20	14	00	43	29	52	34	52	32	64	45	56	39	41	27	58	30	31	18	33	-02	6
7	25	10	38	18	25	00	45	28	56	39	55	34	68	39	55	42	60	41	57	30	43	20	00	-10	7
8	29	10	32	15	20	07	36	24	55	40	57	34	67	43	59	41	50	38	57	30	40	15	20	-07	8
9	20	10	24	04	27	09	40	17	56	30	49	27	68	42	61	39	53	39	57	31	32	19	29	-02	9
10	14	-16	16	-07	26	05	32	14	48	33	41	25	56	43	55	39	59	36	56	32	39	24	00	-13	10
11	-09	-32	-01	-12	21	-01	34	18	54	34	48	34	63	41	57	39	56	34	58	32	45	20	01	-08	11
12	-21	-32	09	-05	12	-01	42	24	52	20	54	35	60	40	55	39	59	35	53	33	40	20	01	-08	12
13	-02	-14	14	-04	13	-04	48	31	38	25	59	41	63	40	56	37	61	36	55	29	41	20	06	-04	13
14	04	-07	21	09	31	06	51	34	49	34	61	43	63	44	55	38	61	35	49	23	46	20	14	04	14
15	08	01	19	02	29	01	51	34	49	33	62	36	61	39	62	43	50	30	51	24	44	19	19	08	15
16	10	00	12	01	18	01	42	19	52	30	49	31	65	44	64	44	56	31	53	29	32	-05	28	12	16
17	08	02	25	08	26	01	34	14	45	27	40	28	63	42	65	37	59	35	55	28	16	-06	26	16	17
18	09	-17	18	08	19	07	32	08	51	28	53	34	67	48	51	37	62	35	54	28	24	06	24	11	18
19	06	-18	21	11	23	08	15	07	51	27	45	30	69	45	57	39	65	37	53	27	26	07	24	08	19
20	05	-04	22	10	33	15	26	14	43	26	57	35	71	48	62	44	59	39	50	31	38	10	18	11	20
21	23	08	19	12	35	16	32	20	51	23	60	41	70	48	58	37	45	35	38	27	32	07	21	10	21
22	14	04	27	08	43	20	40	08	48	30	64	40	66	46	62	40	53	33	40	21	24	03	16	-01	22
23	14	02	18	10	40	21	24	07	44	31	66	43	69	40	56	37	57	32	47	21	33	12	12	-04	23
24	23	08	29	10	32	07	35	15	49	29	66	42	65	41	56	37	62	31	42	26	21	05	28	02	24
25	11	-08	19	10	27	11	32	18	48	30	67	36	65	46	58	40	55	30	42	23	18	06	34	12	25
26	01	-09	32	06	37	21	43	23	47	27	62	42	68	46	60	44	61	30	49	25	34	06	34	04	26
27	11	-03	32	08	44	31	46	11	47	28	66	44	66	40	58	40	65	34	5	26	37	19	23	04	27
28	21	02	17	03	46	12	25	15	49	30	68	45	64	38	52	39	64	34	26	23	31	11	16	05	28
29	22	17			38	24	25	15	51	31	68	46	62	45	54	37	59	30	51	22	31	12	16	05	29
30	28	22			44	26	36	18	53	33	67	40	67	47	59	38	61	30	44	24	36	13	12	-07	30
31	32	24			46	27			57	33			68	45	57	35			45	20			18	00	31
MONTHLY EXTREMES	32	-32	40	-12	46	-07	51	06	57	20	68	25	71	38	69	35	65	27	61	20	46	-06	34	-13	
AVE	14	0	24	8	27	8	36	18	49	30	56	36	65	43	58	40	57	34	51	28	34	12	20	3	AVE

ANNUAL MEAN TEMPERATURE = 32

MAXIMUM = 71, AVERAGE MAXIMUM = 41 MINIMUM = -32, AVERAGE MINIMUM = 22

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

[illegible] PASS - ELEV. 11,314 FT.

YEAR 1964

DAILY TEMPERATURES (F)

DY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	30	10	19	-01	23	-03	47	22	49	20	43	26	58	36	57	41	61	37	52	31	29	16	36	15	1
2	24	10	29	00	30	10	44	14	45	24	41	26	63	41	60	40	60	42	55	21	41	19	32	13	2
3	27	[illegible]	[illegible]	-09	28	04	27	10	35	08	45	28	65	40	61	38	61	31	58	35	38	15	23	03	3
4	12	-04	14	-06	16	-09	21	03	31	10	48	28	71	42	54	38	62	32	58	27	30	09	16	02	4
5	19	-11	32	04	13	00	29	08	43	25	48	29	68	44	61	39	63	39	54	23	47	20	15	-07	5
6	[illegible]	-10	25	-08	15	-07	26	09	35	13	50	30	65	42	62	38	62	35	57	23	51	20	18	-09	6
7	11	-01	[illegible]	-12	11	-08	23	04	38	16	48	33	69	43	63	37	64	34	54	25	42	18	14	-07	7
8	16	-14	[illegible]	-07	15	-01	22	07	40	11	61	28	72	41	61	39	58	35	53	29	44	24	26	02	8
9	[illegible]	-19	16	03	14	-13	30	07	35	11	39	25	71	42	65	41	60	36	53	30	44	19	32	10	9
10	[illegible]	-06	14	10	19	01	34	08	39	16	48	30	71	38	66	40	57	32	53	28	43	22	20	-06	10
11	[illegible]	-13	30	08	11	-10	37	17	44	23	54	30	60	37	65	35	61	34	49	17	34	14	19	-07	11
12	-01	-16	35	03	25	05	42	08	34	12	48	28	68	36	68	39	57	32	38	18	20	00	22	-03	12
13	03	-16	13	-06	32	03	17	05	47	28	55	31	61	37	63	39	61	33	46	24	23	12	03	-16	13
14	13	-13	25	-01	15	-08	25	07	53	29	50	29	65	36	60	37	58	33	54	27	28	05	09	-05	14
15	[illegible]	00	27	-15	15	-03	36	14	56	28	49	30	65	38	63	34	54	30	56	26	20	05	19	07	15
16	19	-04	18	-06	21	-02	45	31	58	33	60	37	67	40	63	38	43	29	52	30	30	11	19	12	16
17	[illegible]	10	10	-09	28	04	44	20	57	34	60	35	69	39	52	31	53	27	53	30	35	16	22	-12	17
18	23	10	[illegible]	-02	39	10	44	24	57	29	63	27	61	39	61	37	59	30	47	11	32	08	22	-12	18
19	17	-02	[illegible]	00	38	04	44	24	49	27	44	29	65	41	68	42	55	25	38	13	24	-01	25	09	19
20	[illegible]	-01	17	-10	16	-09	43	15	53	33	56	28	69	44	56	27	34	20	34	19	11	01	21	04	20
21	33	16	12	-12	25	-01	28	16	61	35	49	31	70	45	45	25	44	25	47	21	21	09	24	08	21
22	29	16	[illegible]	-06	35	13	38	15	61	36	54	23	71	41	41	28	42	24	47	19	29	08	35	11	22
23	20	-03	13	-14	38	03	37	18	56	35	35	24	68	43	53	31	51	25	48	17	35	8	38	31	23
24	07	-11	12	-10	21	08	48	21	53	31	56	33	69	42	58	39	55	26	34	17	21	-01	34	18	24
25	12	-10	25	-01	22	00	46	11	54	39	62	37	58	35	61	36	58	31	32	13	30	05	27	15	25
26	22	04	05	-18	11	04	27	01	60	34	66	38	68	41	59	37	55	37	47	17	30	11	17	05	26
27	28	-02	13	-11	14	03	21	08	43	30	67	40	69	40	59	30	50	19	42	23	33	[illegible]	21	11	27
28	26	-01	06	-12	17	-01	23	10	47	28	68	36	71	42	49	27	50	25	43	21	11	02	24	12	28
29	32	00	25	00	28	07	43	19	49	25	63	34	69	43	59	27	52	28	46	25	19	10	22	-02	29
30	34	07			37	16	49	19	40	23	57	36	68	43	47	29	53	27	54	26	25	17	01	-09	30
31	27	-02			42	14			35	18			62	41	54	34			34	16			15	-01	31
MONTHLY EXTREMES	34	-19	35	-18	42	-13	49	01	61	[illegible]	68	23	72	35	68	25	64	19	54	11	51	-01	38	-16	
AVE	19	-3	16	-5	23	1	35	13	47	25	53	31	67	40	59	35	55	30	48	23	31	11	22	3	AVE

ANNUAL MEAN TEMPERATURE = 29
MAXIMUM = 72, AVERAGE MAXIMUM = 40 MINIMUM = -19, AVERAGE MINIMUM = 17

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

[illegible] PASS - ELEV. 11,314 FT.

YEAR 1965

DAILY TEMPERATURES (F)

DY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	21	05	24	-03	20	-07	45	19	52	24	50	26	60	37	37	28	51	27	32	13	49	25	35	10	1
2	16	-10	25	-03	04	-18	44	16	52	33	46	21	58	32	49	30	57	27	43	22	46	23	21	03	2
3	24	-07	25	16	04	-24	40	15	51	20	48	26	61	32	55	35	47	30	56	28	44	20	26	05	3
4	26	03	30	13	-02	-17	35	13	50	22	47	26	60	32	46	33	47	32	55	29	43	21	35	16	4
5	27	08	26	11	19	-03	29	04	48	18	39	25	64	34	54	32	54	32	54	29	43	22	46	23	5
6	29	11	34	12	30	-01	26	13	36	17	44	27	48	31	53	31	49	32	51	24	42	24	44	19	6
7	34	21	[illegible]	[illegible]	29	03	38	13	41	16	48	30	48	34	54	32	59	36	44	24	39	23	47	19	7
8	34	[illegible]	22	01	35	-01	36	09	38	16	49	29	48	34	55	34	56	35	49	26	44	22	41	18	8
9	22	02	23	-01	31	03	42	23	25	11	55	32	38	31	60	37	52	31	53	26	46	23	39	18	9
10	14	02	16	-01	24	07	39	08	34	14	47	30	46	34	61	35	53	30	54	28	37	18	39	20	10
11	27	02	09	-18	26	03	25	00	33	11	43	28	48	38	64	36	56	31	56	29	34	14	35	18	11
12	21	11	05	-14	31	03	22	00	45	16	44	28	45	37	63	39	53	30	51	26	30	12	21	11	12
13	21	06	-01	-14	21	03	34	11	49	26	45	29	44	32	65	39	52	31	48	27	27	19	20	03	13
14	18	10	10	-09	27	05	31	10	46	21	53	30	47	35	62	35	57	33	44	27	29	16	21	-03	14
15	22	10	18	[illegible]	26	05	33	13	32	21	55	33	49	38	54	33	52	28	49	28	36	17	19	-04	15
16	34	11	14	-12	24	07	37	14	38	18	56	34	50	39	56	34	49	31	56	30	35	20	16	-04	16
17	34	10	19	-01	32	04	39	26	30	25	45	32	57	37	58	35	48	13	44	28	30	21	13	-07	17
18	38	10	33	06	07	-12	37	18	52	26	56	34	53	39	52	37	51	26	47	20	38	20	18	-07	18
19	36	10	40	09	04	-15	34	20	46	29	55	34	53	37	52	36	46	26	35	20	35	15	17	-05	19
20	27	[illegible]	39	11	01	-06	40	26	51	31	54	28	50	39	44	32	33	23	34	16	37	13	20	-01	20
21	36	07	32	[illegible]	11	00	51	26	53	30	55	30	54	38	46	30	29	14	39	16	30	11	28	04	21
22	23	02	32	17	21	11	52	31	50	31	56	32	54	40	51	32	28	14	41	17	23	04	36	08	22
23	15	[illegible]	25	-03	26	12	54	29	52	33	57	33	54	35	57	32	35	24	47	23	29	09	37	13	23
24	24	-03	10	-10	23	10	50	15	46	17	57	34	50	39	56	33	39	25	49	26	30	22	27	-02	24
25	18	-01	15	-01	21	-09	36	14	38	17	50	28	50	38	56	34	46	25	49	26	30	23	22	-01	25
26	03	[illegible]	29	[illegible]	17	-01	34	17	38	17	53	24	50	35	62	37	49	28	49	22	26	12	31	10	26
27	08	-05	[illegible]	11	23	09	29	14	37	15	53	25	49	38	59	36	52	31	47	22	09	-03	14	02	27
28	15	-07	[illegible]	05	32	18	32	10	37	11	54	29	53	34	62	34	54	34	46	18	14	-04	29	04	28
29	20	12			30	10	43	14	47	18	61	30	59	36	63	40	48	24	4	18	13	-05	38	16	29
30	22	17			34	09	49	18	54	27	61	34	61	39	52	31	24	14	41	23	22	-01	36	24	30
31	24	18			42	13			51	27			56	35	52	29			46	24			27	07	31
MONTHLY EXTREMES	38	-10	40	-18	42	-24	54	00	54	11	61	21	64	31	65	28	59	13	58	13	49	-05	47	-07	
AVE	24	5	24	1	22	1	38	15	44	21	51	29	52	36	55	34	48	27	47	24	33	15	29	8	AVE

ANNUAL MEAN TEMPERATURE = 29
MAXIMUM = 65, AVERAGE MAXIMUM = 39 MINIMUM = -24, AVERAGE MINIMUM = 18

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1966

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	19	00	10	-03	25	03	45	21	44	19	48	30	57	40	67	43	53	34	[illegible]	19	33	[illegible]	34	11	1
2	14	-18	16	-05	32	07	44	26	46	21	55	31	61	35	63	43	52	31	52	26	27	05	35	15	2
3	10	-11	18	-09	19	-09	37	07	51	26	58	33	62	40	62	44	49	30	5	23	40	17	33	19	3
4	20	02	16	-08	-05	-17	17	03	54	28	58	30	69	40	62	40	46	29	32	17	39	[illegible]	37	15	4
5	25	01	33	08	01	-18	14	01	57	30	56	26	69	41	63	38	59	32	40	18	28	12	32	10	5
6	27	04	33	04	22	-06	24	07	58	32	46	26	68	41	60	37	59	33	42	26	40	24	32	[illegible]	6
7	29	10	32	10	38	09	39	17	58	32	49	32	71	44	62	40	57	32	45	26	38	[illegible]	33	16	7
8	29	13	21	08	33	11	41	13	58	29	54	26	69	46	62	35	56	32	45	25	35	[illegible]	22	-01	8
9	41	17	18	-03	37	13	43	21	49	29	42	28	66	41	62	38	58	35	47	28	29	04	12	-16	9
10	23	05	09	-11	34	12	47	22	46	26	53	30	69	46	62	34	59	35	45	22	18	05	06	-16	10
11	31	10	07	-13	40	12	43	13	39	20	48	31	70	42	61	39	59	33	54	23	25	[illegible]	21	05	11
12	29	01	08	-11	31	05	33	14	41	10	51	28	62	40	67	40	58	31	47	26	25	09	15	-02	12
13	12	-06	13	-08	41	14	33	10	33	14	51	24	61	42	49	33	50	24	49	29	32	15	[illegible]	03	13
14	17	-04	08	-10	41	19	35	09	40	22	52	32	65	41	58	41	52	31	44	09	39	[illegible]	29	09	14
15	18	04	04	-08	40	11	41	10	50	31	57	34	63	42	63	38	52	26	31	05	[illegible]	[illegible]	[illegible]	00	15
16	14	-09	03	-19	42	22	47	21	47	29	56	32	70	46	67	41	47	27	38	14	44	[illegible]	22	04	16
17	13	-09	07	-10	42	04	46	21	50	25	55	34	70	42	70	41	45	25	37	12	43	[illegible]	[illegible]	[illegible]	17
18	14	-09	18	00	12	05	39	22	46	22	52	33	67	42	67	39	51	29	34	11	39	[illegible]	[illegible]	06	18
19	31	01	22	00	30	12	37	-01	42	23	53	34	65	40	68	40	59	35	24	[illegible]	[illegible]	[illegible]	27	08	[illegible]
20	19	-04	32	04	43	21	22	-03	48	28	60	40	62	40	58	33	60	34	42	11	40	[illegible]	[illegible]	10	20
21	14	-22	20	03	43	19	21	00	50	35	60	30	65	43	50	31	60	35	47	24	41	[illegible]	[illegible]	10	21
22	04	-19	24	-02	31	-05	38	11	55	31	59	37	65	42	52	30	60	[illegible]	[illegible]	11	42	26	[illegible]	-01	22
23	15	-08	21	-08	09	-10	31	13	43	13	58	32	61	42	59	32	63	[illegible]	[illegible]	12	39	18	[illegible]	-08	23
24	07	-12	24	-04	22	02	36	13	44	17	56	34	58	42	57	29	62	[illegible]	32	12	37	18	[illegible]	-04	24
25	04	-12	35	08	37	10	46	20	51	29	63	30	60	41	59	34	58	32	4	20	[illegible]	[illegible]	[illegible]	04	25
26	04	-12	33	04	41	10	49	27	56	30	64	38	63	41	64	39	52	[illegible]	51	26	[illegible]	[illegible]	27	-02	26
27	22	-05	25	03	42	14	47	04	54	31	61	35	67	43	68	37	51	32	49	23	20	-04	16	[illegible]	27
28	30	-03	20	02	43	15	29	06	46	31	67	40	66	43	63	35	50	30	45	26	32	-04	[illegible]	-12	28
29	19	00			43	15	44	28	50	29	68	42	69	46	65	37	53	30	49	27	42	07	-01	-15	29
30	24	04			39	16	44	18	53	34	61	39	70	43	66	40	55	25	42	22	35	24	[illegible]	-10	30
31	39	02			45	16			61	34			72	46	62	38			42	24			[illegible]	[illegible]	31
MONTHLY EXTREMES	41	-22	35	-19	45	-18	49	-03	61	10	68	24	72	35	70	29	63	25	54	05	44	-04	37	-16	
AVE	20	-3	19	-3	32	7	37	13	49	26	56	32	66	42	62	37	55	32	42	20	35	[illegible]	24	2	AVE

ANNUAL MEAN TEMPERATURE = 30
MAXIMUM = 72, AVERAGE MAXIMUM = 41 MINIMUM = -22, AVERAGE MINIMUM = 18

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1967

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	15	-03	33	06	40	13	29	17	16	-01	40	24	65	38	62	42	51	31	54	35	35	17	[illegible]	14	1
2	17	-03	23	-02	43	21	37	13	18	02	47	29	62	37	64	38	55	32	56	37	35	10	21	-08	2
3	11	-12	20	-01	37	15	42	15	25	03	52	32	64	36	62	40	59	39	55	35	10	-08	20	-05	3
4	12	-06	22	00	36	19	49	29	31	05	52	32	64	36	55	36	64	36	57	34	17	-04	37	07	4
5	22	10	32	03	35	-02	41	23	34	15	51	31	59	36	65	40	60	29	51	30	26	-06	31	06	5
6	21	-08	21	-05	10	-13	39	11	39	18	53	32	63	39	63	40	60	31	52	30	28	04	09	-01	6
7	-06	-15	15	-05	16	-09	37	15	35	21	50	26	66	42	63	40	62	36	42	19	36	[illegible]	[illegible]	[illegible]	7
8	-02	-19	10	-11	08	-09	44	22	45	28	48	26	60	39	56	37	59	34	37	23	38	[illegible]	[illegible]	[illegible]	8
9	07	-14	20	-07	23	-01	42	12	51	29	50	27	61	37	58	39	56	33	46	26	41	06	09	-05	9
10	20	00	20	10	38	14	32	08	54	31	50	28	66	40	53	35	56	36	49	26	41	18	-04	-08	10
11	21	11	11	-01	38	19	39	21	42	22	44	27	66	41	59	35	54	33	40	26	26	18	15	-04	11
12	36	12	10	-01	36	17	44	18	41	18	43	25	64	39	64	38	53	31	50	26	41	20	27	-01	12
13	22	03	29	00	38	18	39	18	36	18	47	26	61	36	63	36	45	17	39	28	[illegible]	[illegible]	[illegible]	- 8	13
14	21	12	35	05	36	17	21	11	30	11	45	28	65	39	60	36	40	17	49	27	44	23	04	-17	14
15	16	11	29	-03	31	03	37	15	28	14	44	26	64	41	58	32	46	24	45	15	46	28	29	03	15
16	26	14	09	-03	35	05	43	18	35	17	45	28	55	37	54	32	48	24	27	10	46	22	32	20	16
17	13	-07	06	-02	44	19	25	02	45	24	50	31	54	40	58	32	41	28	39	10	43	19	28	-03	17
18	08	-06	22	02	41	21	44	19	51	24	56	34	53	38	62	36	47	28	46	25	44	20	14	-12	18
19	14	-04	29	08	44	21	48	20	49	31	59	35	57	35	60	33	42	27	50	26	41	21	14	-10	19
20	27	04	17	-11	33	05	44	06	49	23	54	35	63	38	60	34	43	27	46	23	36	19	24	10	20
21	30	13	17	-10	33	08	25	05	40	24	56	32	65	40	56	34	[illegible]	28	5	26	[illegible]	17	[illegible]	[illegible]	21
22	33	15	20	-03	32	09	32	05	52	24	47	32	68	42	59	35	60	32	51	29	30	00	06	-11	22
23	35	06	18	-01	43	14	34	07	56	34	51	34	67	43	60	36	60	33	44	27	18	05	26	-05	23
24	35	06	15	-01	48	21	28	12	60	35	60	27	67	40	65	39	57	34	[illegible]	14	17	[illegible]	[illegible]	18	24
25	21	07	29	08	45	18	33	10	60	33	58	30	59	40	68	43	54	33	35	11	21	12	[illegible]	10	25
26	18	-05	37	10	36	06	29	07	55	32	56	31	64	41	67	35	57	34	44	17	20	-02	22	14	26
27	18	-04	24	05	38	11	38	19	43	24	56	36	65	41	65	39	38	23	24	06	14	-06	22	-07	27
28	26	08	29	06	33	20	47	25	50	28	58	37	65	34	64	36	49	23	35	12	27	-03	15	07	28
29	32	10			44	31	48	30	41	26	55	30	64	38	60	37	58	30	45	10	31	04	22	-02	29
30	35	09			45	05	48	05	44	26	59	34	70	40	56	35	60	34	18	06	24	06	11	00	30
31	29	13			11	01			46	27			66	42	52	34			24	06			08	-12	31
MONTHLY EXTREMES	36	-19	37	-11	48	-13	49	02	60	-01	60	24	70	34	68	32	64	17	57	06	48	-08	37	-18	
AVE	20	2	22	-0	35	11	38	15	42	21	51	30	63	39	60	37	53	30	43	21	32	10	19	-1	AVE

ANNUAL MEAN TEMPERATURE = 29
MAXIMUM = 70, AVERAGE MAXIMUM = 40 MINIMUM = -19, AVERAGE MINIMUM = 18

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1968

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	10	-10	21	-02	31	08	41	21	47	21	50	28	51	26	48	36	58	28	50	28	32	17	29	-02	1
2	14	02	18	-02	36	08	41	15	51	22	56	30	57	31	53	39	60	29	43	28	31	18	13	-04	2
3	12	01	28	05	34	-01	32	04	48	21	59	35	61	34	53	41	52	29	45	28	31	15	05	-04	3
4	07	-06	16	09	31	-01	14	01	48	23	61	35	62	36	52	37	41	24	54	26	40	21	20	-01	4
5	17	-07	21	03	35	06	22	03	47	23	60	35	58	36	58	41	38	24	47	29	32	14	30	08	5
6	20	-03	32	05	45	12	36	08	45	25	59	36	50	32	58	38	49	26	42	24	30	03	27	12	6
7	09	-07	34	05	40	13	36	03	41	06	56	32	59	35	59	39	54	28	46	26	24	-02	25	00	7
8	28	-03	29	08	35	12	14	-05	29	06	51	30	65	36	56	41	56	33	44	25	24	-02	29	06	8
9	24	-01	32	06	28	13	20	-01	41	20	47	22	60	37	54	42	56	31	32	10	23	00	33	07	9
10	28	03	34	07	29	03	33	05	42	19	45	23	62	39	50	41	60	32	37	10	26	03	33	11	10
11	24	04	36	08	20	-02	43	12	40	15	44	24	61	39	45	39	63	36	47	21	20	00	38	12	11
12	14	-16	30	02	20	-05	46	20	44	21	50	30	62	36	50	35	62	36	45	29	31	02	34	00	12
13	16	-11	11	-02	30	-03	42	23	44	19	59	38	60	39	53	36	58	31	45	28	39	05	02	-08	13
14	34	12	29	07	37	12	34	-02	38	19	55	32	68	43	54	36	55	32	50	32	27	09	12	-10	14
15	36	10	24	07	21	07	35	17	41	16	51	30	66	41	47	28	55	33	55	32	21	01	34	08	15
16	39	11	22	06	21	02	41	21	34	15	53	30	60	39	50	30	45	18	47	11	24	02	33	08	16
17	36	14	22	05	36	15	27	18	31	14	55	33	66	40	58	34	32	19	22	06	16	-01	32	07	17
18	18	-09	24	07	33	04	26	08	35	14	58	34	68	41	58	33	32	19	20	01	07	00	16	-06	18
19	21	-08	23	09	20	-03	30	08	38	12	62	37	66	42	55	35	49	27	39	05	21	04	00	-13	19
20	34	12	25	09	22	-03	21	09	42	25	64	39	67	41	59	34	57	27	43	15	27	11	17	-12	20
21	34	11	32	11	21	-11	34	09	38	26	65	37	66	41	63	36	56	30	46	25	34	13	15	-02	21
22	38	10	29	12	16	-02	37	09	56	27	64	38	67	46	60	36	51	29	38	17	42	13	10	-15	22
23	23	07	22	12	25	07	23	-04	51	26	65	38	64	39	53	27	44	19	39	19	36	13	11	-14	23
24	30	09	24	14	44	14	30	04	42	25	67	35	59	39	46	25	43	19	35	22	21	04	25	06	24
25	37	14	27	02	34	14	34	14	41	19	60	28	65	41	60	29	51	22	41	22	34	18	33	08	25
26	38	10	28	02	42	14	31	11	40	20	47	27	66	42	61	38	53	24	51	24	18	-04	25	07	26
27	34	05	33	06	33	02	27	11	41	23	57	36	59	43	60	39	58	29	48	19	21	-03	26	-01	27
28	30	04	20	06	34	02	28	04	43	25	65	40	54	40	54	34	54	31	40	23	24	01	09	-02	28
29	26	05	16	06	42	18	33	12	53	31	64	46	63	37	54	34	49	27	48	25	14	-12	15	04	29
30	22	09			45	19	47	14	56	31	63	21	65	40	49	27	49	26	54	26	18	-12	16	00	30
31	28	13			46	14			57	27			59	35	49	27			50	23			04	-06	31
MONTHLY EXTREMES	39	-16	36	-02	46	-11	47	-05	57	06	67	21	68	26	63	25	63	18	55	01	42	-12	38	-15	
AVE	25	3	26	6	32	6	32	9	43	21	57	33	62	38	54	35	51	27	43	21	26	5	21	0	AVE

ANNUAL MEAN TEMPERATURE = 28
MAXIMUM = 68, AVERAGE MAXIMUM = 39 MINIMUM = -16, AVERAGE MINIMUM = 17

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1969

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	18	06	12	-08	33	06	45	24	44	20	45	21	61	34	66	42	58	34	50	28	24	12	39	17	1
2	31	12	10	-10	30	02	35	11	48	26	40	22	66	42	67	43	60	34	47	30	19	05	41	16	2
3	25	02	-03	-15	22	-03	45	16	52	26	47	27	67	47	71	43	63	35	53	24	14	-02	40	16	3
4	18	-01	18	-09	28	-02	44	20	49	25	51	31	69	40	66	42	58	35	30	19	25	05	39	17	4
5	23	05	36	06	18	-03	35	15	46	28	57	36	62	36	64	43	56	35	25	10	36	12	27	11	5
6	27	22	27	06	17	-04	47	24	40	28	64	37	59	39	70	44	58	37	26	10	39	14	15	-01	6
7	32	16	25	07	30	-01	46	10	37	27	60	33	64	38	70	43	61	38	33	12	38	16	10	-07	7
8	38	10	16	-05	05	-10	20	09	29	19	49	33	65	37	70	46	60	34	40	16	41	06	12	-08	8
9	12	-15	24	-04	10	-11	33	12	45	22	52	32	64	36	72	44	57	35	47	20	34	14	10	-05	9
10	17	-14	34	02	11	-11	39	18	46	21	58	34	62	39	72	46	57	34	38	20	36	16	15	-01	10
11	20	05	30	08	17	-08	45	20	48	25	56	28	67	40	72	44	48	33	31	12	33	14	07	00	11
12	26	14	32	11	21	-14	45	23	49	27	40	29	69	40	69	41	58	33	14	-01	27	15	21	05	12
13	33	13	31	11	18	-12	35	22	49	26	47	27	62	40	63	38	54	30	21	00	25	16	34	11	13
14	38	14	32	06	16	-09	38	16	53	26	47	29	68	41	57	39	52	30	30	10	20	08	36	11	14
15	38	20	29	02	21	-03	42	20	51	27	44	30	65	40	63	37	55	32	36	14	25	08	42	12	15
16	28	06	29	02	31	04	35	14	49	26	45	31	69	48	62	38	52	30	23	04	38	14	42	12	16
17	28	11	27	04	37	08	30	12	42	22	48	31	68	43	66	38	50	30	29	12	32	04	39	12	17
18	23	-01	21	-03	37	08	33	09	51	28	38	30	67	44	60	39	46	30	41	23	13	-06	37	14	18
19	23	-01	33	00	36	06	43	17	52	31	43	31	63	43	63	36	55	30	38	19	06	-08	36	12	19
20	29	11	28	05	19	-03	47	24	56	30	53	33	55	41	58	37	57	32	30	05	22	-04	35	14	20
21	34	11	20	03	28	02	48	23	58	32	57	37	53	37	56	37	51	31	38	07	34	12	25	17	21
22	37	12	23	00	38	12	53	29	51	29	61	32	63	39	60	38	51	29	39	22	40	13	33	15	22
23	23	03	21	-01	37	10	55	27	55	29	56	32	65	42	60	36	38	25	43	20	33	04	19	04	23
24	09	-15	27	02	21	-01	52	27	55	29	45	31	66	44	62	38	51	25	33	13	35	04	25	07	24
25	17	-14	23	14	17	-03	51	10	55	32	47	23	68	42	65	38	52	27	42	13	36	06	23	-06	25
26	27	16	39	19	12	-01	24	07	59	35	33	24	68	44	65	39	53	27	39	15	36	07	23	10	26
27	30	18	34	-01	26	05	25	09	61	37	35	23	65	39	68	40	58	29	44	16	32	-04	24	02	27
28	27	04	18	-01	34	08	28	10	62	35	55	29	69	43	69	42	59	35	40	12	27	-01	10	-08	28
29	19	-05			38	15	42	15	58	34	63	30	73	44	65	41	57	34	37	09	34	06	09	-12	29
30	14	-15			38	19	45	24	59	36	61	30	64	45	61	41	61	34	17	10	34	15	07	-12	30
31	14	-03			41	25			57	32			61	41	56	35			21	11			03	-09	31
MONTHLY EXTREMES	38	-15	39	-15	41	-14	55	07	62	19	64	21	73	34	72	35	63	25	53	-01	41	-08	42	-12	
AVE	25	5	25	2	25	1	40	17	51	28	50	30	65	41	65	40	55	32	35	14	30	7	25	5	AVE

ANNUAL MEAN TEMPERATURE = 30
MAXIMUM = 73, AVERAGE MAXIMUM = 41 MINIMUM = -15, AVERAGE MINIMUM = 19

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1970

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	03	-12	29	-01	35	08	19	-03	29	03	35	14	62	36	63	41	62	38	50	28	35	14	29	05	1
2	04	-15	10	-01	33	11	16	-01	27	04	40	19	64	40	68	41	60	34	48	28	22	06	30	06	2
3	-02	-12	07	-01	32	10	24	06	38	12	47	24	67	42	64	43	58	36	54	28	21	06	31	05	3
4	00	-10	19	06	24	04	18	-08	45	22	49	25	65	41	66	44	57	37	55	30	22	01	22	05	4
5	08	-15	19	04	27	06	25	08	51	25	47	23	68	38	63	42	55	36	54	28	39	13	30	08	5
6	-01	-22	29	07	25	03	32	11	51	28	52	29	62	38	61	46	54	38	48	28	32	23	28	10	6
7	03	-21	31	12	29	07	46	13	50	27	53	30	62	41	66	45	44	32	41	28	40	21	35	15	7
8	03	-10	34	03	36	12	42	15	48	15	52	31	50	40	60	42	50	33	20	07	38	15	39	11	8
9	18	-09	31	03	39	12	36	11	36	21	50	29	56	41	62	40	54	38	21	07	22	04	31	17	9
10	21	10	36	08	26	03	43	15	37	16	49	26	61	38	66	41	52	31	29	11	31	14	36	17	10
11	21	05	36	10	20	-05	39	20	46	29	42	27	62	40	68	41	58	32	34	10	35	00	15	-02	11
12	21	05	38	12	18	-07	38	05	50	30	36	25	60	38	69	43	56	38	32	15	26	08	20	-05	12
13	22	04	30	12	22	-02	16	-01	49	25	42	25	59	37	67	43	56	29	48	20	33	10	20	00	13
14	25	04	28	02	22	09	34	13	46	18	57	32	65	45	68	46	52	33	45	22	22	07	30	04	14
15	28	06	22	03	32	09	36	07	33	09	55	32	66	40	66	43	50	26	28	09	16	01	28	08	15
16	23	03	23	06	29	02	23	03	42	18	51	28	66	42	53	37	52	28	34	12	35	09	18	06	16
17	26	05	37	16	28	07	35	17	54	33	56	35	66	41	67	41	49	26	42	14	35	10	31	12	17
18	25	06	37	-01	27	-02	35	15	55	36	58	34	65	43	61	36	55	32	40	14	25	08	30	10	18
19	19	12	17	-08	11	-13	22	09	56	36	59	30	65	42	63	40	60	33	44	15	21	05	20	-01	19
20	22	15	19	-08	16	-12	22	03	34	26	57	34	65	40	60	42	56	39	36	17	16	03	16	-01	20
21	23	14	33	01	24	-05	18	04	55	33	57	36	62	40	54	42	55	24	43	19	34	07	23	-05	21
22	28	14	33	09	22	02	32	07	56	30	59	36	67	38	52	34	36	22	32	19	29	20	17	-03	22
23	27	22	31	10	23	02	24	03	52	27	62	35	55	37	55	37	38	17	35	17	24	15	10	-11	23
24	36	22	32	07	31	12	27	02	53	29	60	36	58	38	59	37	45	22	33	16	30	21	08	-09	24
25	35	11	26	05	34	01	32	14	54	28	62	41	62	38	61	40	42	15	40	10	36	26	08	-02	25
26	24	11	25	03	11	-06	44	24	51	29	65	40	62	38	65	44	30	08	25	-01	38	24	23	-02	26
27	30	11	30	01	17	-03	42	20	52	29	69	45	61	37	62	41	37	12	20	-04	28	12	24	-01	27
28	35	-01	33	02	21	-04	46	14	52	29	70	46	58	35	63	40	45	19	18	01	29	08	16	-01	28
29	02	-08			30	03	30	-01	48	27	70	40	60	36	63	41	47	23	23	03	31	13	14	-04	29
30	03	-12			25	04	24	01	49	25	64	41	62	42	67	45	48	29	28	17	37	15	25	-01	30
31	25	-07			13	-04			51	21			63	42	62	38			34	19			16	01	31
MONTHLY EXTREMES	36	-22	38	-08	39	-13	46	-08	56	03	70	14	68	35	69	34	62	08	55	-04	40	00	39	-11	
AVE	18	1	28	4	25	2	31	8	47	24	54	32	62	39	63	41	50	29	37	16	29	11	23	3	AVE

ANNUAL MEAN TEMPERATURE = 29

MAXIMUM = 70, AVERAGE MAXIMUM = 39 MINIMUM = -22, AVERAGE MINIMUM = 18

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1971

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	26	08	35	19	07	-20	35	00	44	19	48	27	54	35	59	34	58	36	5	28	33	04	18	-02	1
2	18	01	42	11	12	-14	18	-01	47	23	52	29	56	36	64	38	64	38	29	14	24	04	20	01	2
3	04	-18	35	12	10	-15	33	10	52	26	52	29	60	39	60	38	60	37	31	14	20	05	18	-01	3
4	-12	-23	22	-07	23	05	29	-01	53	27	54	26	60	35	66	40	57	25	38	17	34	13	23	-02	4
5	-12	-28	10	-07	22	05	22	03	50	18	41	28	61	35	62	39	34	25	42	22	41	23	15	-11	5
6	-15	-32	02	-09	16	-10	33	06	33	19	48	27	63	43	64	39	50	31	48	26	26	05	15	-03	6
7	-10	-27	02	-18	10	-10	45	21	35	21	47	26	61	37	62	36	64	40	52	27	28	08	24	02	7
8	05	-16	05	-16	24	03	45	16	37	23	52	31	56	36	62	34	61	30	55	25	42	12	08	-06	8
9	17	-05	11	-03	31	-05	35	15	41	18	54	29	59	34	64	37	49	29	44	21	31	09	15	-04	9
10	23	10	22	03	25	06	43	26	35	22	48	30	61	40	62	36	60	34	47	21	40	16	26	-11	10
11	25	10	27	12	28	06	47	32	33	22	47	30	64	40	59	39	64	34	50	26	49	23	12	-11	11
12	31	16	19	07	30	08	48	31	36	18	51	31	66	42	64	38	63	37	49	29	49	24	12	-13	12
13	29	08	27	10	37	22	45	12	50	22	46	28	68	44	60	40	64	39	45	22	47	18	14	-03	13
14	10	-03	37	13	29	-01	43	23	52	29	50	29	72	46	62	38	63	36	49	23	25	07	15	-04	14
15	15	06	35	08	13	01	49	25	44	26	53	33	66	42	62	37	59	27	56	33	38	17	16	-03	15
16	29	11	37	11	17	01	44	22	50	28	54	35	70	43	66	40	50	24	48	26	34	17	07	-06	16
17	37	24	22	03	26	04	45	26	51	20	58	36	70	46	66	43	47	14	40	28	30	08	08	-09	17
18	33	23	35	13	33	-08	45	19	35	12	59	38	74	43	69	44	19	08	37	13	17	-04	27	03	18
19	28	14	23	03	11	-11	41	21	31	13	57	33	60	43	63	41	24	04	23	08	09	-08	37	04	19
20	30	15	28	01	27	00	28	13	34	18	57	36	49	34	60	41	33	10	30	10	22	00	22	00	20
21	38	01	09	-12	36	-07	26	18	46	26	60	35	62	40	61	38	38	10	40	22	38	16	23	07	21
22	24	05	10	-16	36	16	37	18	53	28	62	38	55	38	65	42	31	18	41	17	40	13	27	08	22
23	18	-03	24	-07	32	23	38	13	47	23	61	39	57	38	64	41	36	16	37	17	17	04	35	11	23
24	15	04	18	-04	30	20	38	17	38	18	64	43	56	35	63	41	45	25	44	18	22	04	34	15	24
25	23	08	23	-01	29	14	40	20	42	24	67	44	55	37	63	40	47	25	43	21	33	08	39	28	25
26	23	13	26	-09	39	17	40	20	49	28	66	44	58	36	64	44	50	29	28	20	32	04	35	25	26
27	32	15	04	-15	50	30	28	12	53	31	66	41	60	40	62	42	53	32	29	18	26	11	37	05	27
28	28	08	05	-16	42	07	30	11	57	33	62	39	60	38	60	40	52	22	36	14	23	01	18	-02	28
29	32	09			29	11	37	13	56	29	62	40	60	36	59	39	50	27	27	07	17	05	22	03	29
30	33	19			39	19	37	17	48	21	58	33	59	30	55	38	50	31	16	-03	18	-03	15	-01	30
31	38	23			47	30			38	22			62	40	57	34			31	01			07	-10	31
MONTHLY EXTREMES	38	-32	42	-18	50	-20	49	-01	57	12	67	26	74	30	69	34	64	04	56	-03	49	-08	39	-13	
AVE	20	3	21	-1	27	5	37	16	44	23	55	34	61	39	62	39	50	26	4	19	30	9	21	0	AVE

ANNUAL MEAN TEMPERATURE = 29

MAXIMUM = 74, AVERAGE MAXIMUM = 39 MINIMUM = -32, AVERAGE MINIMUM = 18

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1972

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	20	-06	24	-05	36	-01	22	09	37	-03	55	31	64	41	64	40	51	37	52	28	28	09	22	08	1
2	13	05	18	-17	15	-04	31	17	32	07	59	39	62	38	64	41	41	35	54	30	16	09	28	09	2
3	22	-17	02	-22	25	11	33	13	38	15	59	34	61	37	62	37	51	35	54	31	21	10	32	09	3
4	-15	-28	15	-05	25	12	33	14	45	23	55	34	58	33	62	40	50	32	56	31	27	09	32	15	4
5	10	-25	28	-03	29	13	40	18	51	26	55	34	58	33	64	37	55	34	49	32	37	12	23	01	5
6	14	03	28	07	35	24	45	32	45	24	53	33	62	40	57	37	57	38	40	26	33	16	02	-22	6
7	25	05	19	02	41	19	42	15	34	19	57	33	57	39	65	41	44	33	46	29	25	05	10	-03	7
8	34	08	20	00	30	08	39	20	37	19	60	34	60	39	63	41	49	33	50	33	41	13	17	05	8
9	22	-02	21	05	37	15	44	29	47	25	55	33	64	44	62	38	57	36	42	30	35	14	16	01	9
10	20	-02	17	-03	47	19	47	29	49	24	50	33	60	37	64	40	54	34	43	32	21	03	11	-18	10
11	12	01	16	-08	46	25	48	30	43	16	58	36	60	39	72	46	51	33	47	29	30	04	13	-18	11
12	18	11	21	-07	44	17	43	21	37	17	60	37	64	40	72	46	51	35	46	29	30	07	21	-03	12
13	16	-05	20	01	40	20	32	17	33	17	58	35	66	42	70	44	57	34	50	31	17	09	12	-06	13
14	-01	-06	29	04	43	19	39	15	34	15	57	34	67	42	71	42	55	34	49	27	20	04	11	-08	14
15	06	-09	04	04	32	06	28	11	47	23	55	33	68	41	64	42	54	34	46	27	34	04	12	-14	15
16	32	-03	16	07	30	11	40	10	53	27	56	34	65	43	60	42	56	30	48	27	19	07	18	-02	16
17	34	04	23	10	37	16	44	25	56	33	59	34	69	40	54	37	54	30	42	26	26	05	28	06	17
18	26	07	21	10	39	17	44	19	55	30	56	34	60	37	60	38	58	37	43	27	27	07	30	12	18
19	30	15	33	09	45	18	40	19	52	31	55	34	61	43	60	39	58	37	38	26	22	07	22	07	19
20	32	17	35	13	33	10	34	11	44	29	52	32	66	39	50	37	51	29	39	26	24	05	24	09	20
21	27	07	36	13	25	08	31	10	52	27	49	36	54	39	55	35	39	26	43	19	19	00	21	06	21
22	32	13	38	17	42	18	33	12	53	21	56	37	61	40	56	34	51	28	24	17	17	00	27	06	22
23	25	20	36	18	50	20	39	08	42	19	57	38	62	40	56	35	54	31	26	13	28	-04	31	11	23
24	32	-01	27	14	37	10	40	17	44	23	57	31	64	44	55	30	46	34	27	10	36	07	19	02	24
25	17	-01	23	07	36	13	48	23	51	29	57	38	62	42	42	31	48	32	33	13	25	00	30	04	25
26	27	16	20	-04	42	25	45	14	53	29	59	33	62	42	51	32	47	30	39	16	19	00	12	00	26
27	32	10	27	10	37	-04	19	11	55	29	56	34	61	39	54	34	50	31	40	16	22	07	26	01	27
28	13	00	35	13	20	00	25	14	50	27	57	35	61	36	57	38	52	30	30	15	08	-09	39	16	28
29	05	-16	42	27	16	-08	37	16	47	22	62	38	62	37	59	40	41	22	29	13	09	-09	33	09	29
30	09	-20			15	03	48	18	49	25	63	38	68	45	56	38	38	22	33	-02	12	-05	10	-06	30
31	15	-07			15	03			54	28			69	46	53	36			14	-01			01	-11	31
MONTHLY EXTREMES	34	-28	42	-22	50	-08	48	08	56	-03	63	31	69	33	72	30	58	22	56	-02	41	-09	39	-22	
AVE	19	-0	24	4	34	12	38	17	46	22	57	35	63	40	60	38	51	32	41	23	24	5	20	1	AVE

ANNUAL MEAN TEMPERATURE = 30
MAXIMUM = 72, AVERAGE MAXIMUM = 40 MINIMUM = -28, AVERAGE MINIMUM = 19

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1973

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	04	-12	19	-04	34	13	24	07	37	13	56	30	71	49	53	32	50	34	48	27	29	20	41	19	1
2	10	-08	12	-07	30	07	29	07	30	11	48	27	69	44	57	34	53	27	50	30	30	08	43	21	2
3	21	-03	26	-05	33	08	25	05	30	09	40	22	70	45	58	36	40	23	50	28	28	18	35	06	3
4	20	-02	38	04	21	-04	20	-04	42	22	42	25	69	44	60	37	50	28	44	18	37	08	22	-01	4
5	11	-05	32	11	29	-02	37	01	49	21	36	15	71	48	59	38	54	32	47	26	20	10	06	-05	5
6	09	-04	21	04	20	01	37	14	46	24	45	18	72	48	51	38	62	37	47	30	33	16	10	-08	6
7	19	-05	29	06	20	-01	38	01	30	23	52	29	76	45	57	36	62	35	48	30	37	25	18	02	7
8	10	-07	29	00	21	00	03	-12	35	17	55	32	69	41	56	37	63	40	51	29	41	26	28	15	8
9	12	-03	24	-03	21	03	11	-09	41	16	61	36	64	41	56	36	63	39	46	22	44	21	22	00	9
10	15	-02	24	-01	30	06	14	-06	43	21	63	40	60	40	60	39	60	41	36	11	47	24	25	02	10
11	11	-11	21	04	28	02	29	11	48	28	62	37	64	41	66	40	54	39	27	14	44	26	33	05	11
12	19	-10	28	09	38	07	35	10	49	21	60	32	68	45	61	41	49	36	36	15	45	25	38	05	12
13	23	15	25	-03	36	08	37	12	48	20	56	36	64	40	64	40	52	34	31	19	47	29	24	06	13
14	30	18	17	-05	33	06	42	15	46	19	58	34	49	34	64	42	58	38	44	25	45	19	27	05	14
15	32	14	16	-08	16	-02	44	16	41	19	46	30	47	35	63	37	62	38	52	28	21	01	13	02	15
16	41	08	24	-08	22	00	27	-01	47	23	44	23	52	34	65	40	53	34	52	29	28	09	26	-01	16
17	30	08	28	-03	28	01	32	04	50	23	39	28	53	37	67	47	46	23	48	26	37	11	32	12	17
18	23	08	28	-02	38	06	42	16	52	29	49	18	58	39	64	40	50	32	50	26	33	12	35	12	18
19	22	07	27	-04	32	08	40	10	53	30	35	14	50	42	60	40	58	33	46	26	39	13	17	-07	19
20	29	05	13	-06	30	06	14	07	51	30	40	26	52	36	66	47	55	32	50	29	21	02	10	-08	20
21	14	-03	29	-04	41	06	20	08	50	29	48	28	51	32	66	40	60	28	46	26	18	-01	28	01	21
22	11	-08	35	00	32	03	24	08	50	27	51	31	52	32	61	40	52	27	49	24	19	01	37	14	22
23	11	11	34	09	26	01	29	09	43	25	58	35	56	32	52	36	58	37	52	30	18	-01	31	07	23
24	23	-11	30	10	25	00	40	16	45	30	59	38	55	34	63	43	54	23	53	15	20	04	13	02	24
25	40	08	30	08	20	-01	39	17	43	27	56	38	57	30	58	43	35	23	28	15	17	02	09	-07	25
26	40	10	22	04	28	02	33	10	45	19	60	38	51	32	62	38	41	20	40	21	19	01	16	-08	26
27	28	-02	34	11	32	02	32	06	30	14	63	38	60	36	64	39	26	12	35	10	16	-05	09	-11	27
28	12	-10	41	10	26	06	42	07	32	11	63	38	55	34	64	40	37	19	34	20	08	-05	17	05	28
29	29	-01			22	03	45	23	43	21	63	36	57	34	57	37	28	23	44	25	35	07	18	00	29
30	36	16			22	03	44	21	43	23	64	40	53	34	58	37	34	22	43	14	44	31	22	07	30
31	32	04			28	00			44	21			52	33	54	37			25	15			13	-13	31
MONTHLY EXTREMES	41	-12	41	-08	41	-04	45	-12	53	09	64	14	76	30	67	32	63	12	53	10	47	-05	43	-13	
AVE	22	1	26	1	28	3	31	8	43	21	52	30	60	38	60	39	51	30	43	23	31	12	23	3	AVE

ANNUAL MEAN TEMPERATURE = 29
MAXIMUM = 76, AVERAGE MAXIMUM = 39 MINIMUM = -13, AVERAGE MINIMUM = 18

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1974

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	-02	-19	32	13	42	17	28	02	42	17	50	30	70	42	60	38	63	44	48	28	24	17	18	-03	1
2	03	-20	23	01	40	17	26	08	45	25	46	30	63	44	60	38	62	32	50	27	33	13	33	09	2
3	03	-20	12	00	38	05	31	07	43	23	53	31	66	38	55	34	48	26	54	29	33	12	37	15	3
4	10	-09	17	03	21	-05	17	02	46	22	51	31	60	36	57	36	55	32	52	29	18	07	33	10	4
5	15	-01	29	05	15	-04	20	03	45	19	51	36	69	43	60	38	58	39	41	29	20	03	33	13	5
6	17	00	10	-07	26	-02	34	13	52	25	41	28	67	42	57	38	58	33	41	20	34	07	26	13	6
7	07	00	14	-11	34	08	35	06	50	28	40	20	68	40	60	40	60	34	43	25	29	07	20	05	7
8	13	06	03	-15	38	19	19	02	48	31	41	20	56	38	58	38	62	40	44	24	37	12	15	-09	8
9	14	04	05	-12	36	10	35	14	50	32	27	19	58	40	54	36	62	40	48	29	34	16	20	-01	9
10	20	-04	25	-01	26	11	47	10	52	32	42	27	66	42	56	30	66	44	52	28	26	09	31	07	10
11	05	-03	30	02	27	12	23	07	45	24	50	28	62	40	48	32	62	44	48	27	18	02	28	00	11
12	18	-02	30	02	27	07	20	13	43	28	54	31	70	44	53	36	60	25	37	24	22	08	20	01	12
13	25	05	31	04	36	07	28	03	52	28	58	32	66	42	62	39	36	23	30	21	31	21	18	00	13
14	30	06	29	01	37	16	18	-01	38	12	58	36	68	43	60	40	43	26	38	20	22	14	20	-01	14
15	35	07	29	02	35	20	27	01	41	17	62	37	60	41	60	41	42	25	34	16	28	17	06	-02	15
16	41	17	29	02	32	17	30	08	51	35	61	38	63	42	63	40	32	26	40	25	28	08	11	-03	16
17	42	17	35	03	40	25	41	10	52	30	58	34	60	42	66	44	34	25	48	30	31	10	18	-02	17
18	38	16	33	06	43	21	41	15	50	26	59	35	58	42	66	41	43	26	55	31	36	10	26	03	18
19	30	09	17	01	34	11	49	22	54	33	61	40	61	42	68	46	48	27	55	30	30	07	14	04	19
20	27	11	25	03	30	04	42	07	50	17	67	44	66	40	62	41	48	26	51	29	19	02	06	01	20
21	27	12	10	-13	17	-07	32	14	32	16	66	39	60	44	61	36	49	22	51	28	34	12	22	05	21
22	25	-10	14	-10	24	04	29	15	37	16	64	37	59	40	61	37	48	24	44	27	39	15	26	-03	22
23	05	-10	28	-11	16	06	42	17	44	26	65	38	58	40	62	38	52	27	39	25	41	14	02	-08	23
24	08	-07	06	-13	15	-01	49	28	48	28	65	36	63	42	66	40	54	30	46	26	20	02	01	-15	24
25	20	-03	12	-16	24	11	52	25	48	28	68	41	59	39	64	42	47	26	35	25	22	09	-02	-18	25
26	30	-04	32	-01	35	13	52	25	49	31	68	43	62	43	62	40	50	26	38	22	38	08	26	-09	26
27	13	-10	34	13	38	16	45	20	53	35	68	42	62	40	64	39	52	25	40	22	25	00	20	-05	27
28	12	-04	27	13	39	17	40	10	58	36	70	42	65	40	60	38	44	16	34	21	33	07	24	-02	28
29	16	-01			37	09	36	16	56	32	68	41	64	39	62	43	36	20	36	23	07	-09	28	02	29
30	18	03			32	10	37	11	56	28	70	43	55	38	62	44	46	25	29	17	17	-08	23	-04	30
31	23	07			42	18			51	28			64	40	64	43			25	09			17	-08	31
MONTHLY EXTREMES	42	-20	35	-16	43	-07	52	-01	58	12	70	19	70	36	68	30	66	16	55	09	41	-09	37	-18	
AVE	19	-0	22	-1	31	10	34	11	48	26	57	34	63	41	60	39	51	29	43	25	28	8	20	-0	AVE

ANNUAL MEAN TEMPERATURE = 30

MAXIMUM = 70, AVERAGE MAXIMUM = 40 MINIMUM = -20, AVERAGE MINIMUM = 19

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1975

DAILY TEMPERATURES (F)

DAY	JAN MAX	JAN MIN	FEB MAX	FEB MIN	MAR MAX	MAR MIN	APR MAX	APR MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUG MAX	AUG MIN	SEPT MAX	SEPT MIN	OCT MAX	OCT MIN	NOV MAX	NOV MIN	DEC MAX	DEC MIN	DAY
1	13	-07	15	00	26	16	32	11	29	08	40	26	66	40	57	36	68	39	43	22	36	15	17	-08	1
2	25	-02	22	00	38	14	23	-07	40	11	45	26	68	40	58	33	67	43	50	26	40	18	23	15	2
3	06	-11	30	01	32	14	15	-04	35	13	52	31	67	39	59	34	63	38	54	28	40	20	34	12	3
4	09	-08	28	01	23	04	38	15	42	22	53	28	65	37	62	38	64	40	55	28	43	20	38	16	4
5	20	-03	18	-05	34	14	42	20	48	20	46	27	65	35	66	41	60	33	51	30	52	24	41	10	5
6	12	00	07	-08	33	15	45	22	40	09	54	32	61	37	70	46	60	34	55	30	54	27	30	11	6
7	24	12	12	-07	27	14	43	19	22	08	54	33	62	37	66	46	63	37	62	30	42	19	31	12	7
8	20	-07	24	11	30	14	29	02	26	14	55	30	61	39	68	44	64	39	53	13	40	22	28	12	8
9	21	04	24	09	40	16	17	-03	40	17	46	22	59	37	68	43	54	39	29	12	26	06	29	16	9
10	08	-17	30	11	26	09	26	06	47	23	39	21	59	35	67	44	56	38	47	26	29	-01	33	17	10
11	-05	-13	19	04	29	08	24	10	46	22	31	14	57	34	66	40	54	37	53	31	36	00	37	10	11
12	-02	-29	16	-02	24	01	25	07	50	25	42	26	57	32	63	39	44	33	56	36	05	-08	26	13	12
13	16	-20	30	-02	26	-03	30	02	38	20	49	30	56	33	58	40	52	31	56	24	30	-04	26	08	13
14	21	10	32	12	26	02	30	11	43	22	52	36	58	36	50	34	46	32	31	13	36	14	21	02	14
15	31	08	19	05	30	11	36	18	53	30	46	33	60	36	52	32	44	30	26	15	42	18	14	-12	15
16	26	14	22	01	28	03	40	18	55	30	51	33	57	36	56	34	49	30	42	14	43	18	19	-07	16
17	33	08	18	00	35	08	40	19	55	27	44	27	60	34	58	36	52	32	37	21	47	27	22	02	17
18	24	10	17	-08	25	-02	33	09	50	27	48	31	55	36	60	39	53	32	56	21	49	17	09	-04	18
19	30	04	11	-11	30	06	20	10	46	27	48	26	58	38	61	38	46	24	51	25	37	02	28	-01	19
20	24	04	15	-03	40	18	33	09	48	29	43	26	64	42	63	40	43	25	51	25	07	-07	28	05	20
21	29	00	14	-14	40	19	34	13	48	29	48	26	60	34	58	40	46	20	49	24	17	02	37	08	21
22	06	-08	08	-14	28	19	42	25	42	22	42	26	60	37	57	35	45	23	50	27	19	-03	26	04	22
23	24	02	07	-17	28	-01	44	19	37	14	46	27	60	38	55	34	53	28	51	16	27	00	28	07	23
24	26	12	19	-01	13	00	41	20	34	20	52	33	61	37	59	40	54	28	19	02	15	04	22	-02	24
25	23	13	30	01	22	04	43	28	46	30	58	37	56	37	57	28	57	29	14	-05	17	03	12	01	25
26	28	18	28	-03	30	19	50	27	43	16	57	19	58	36	56	34	54	30	37	09	03	-11	19	07	26
27	33	09	27	10	31	-04	46	26	48	22	57	32	62	36	64	39	53	28	45	25	08	-09	18	10	27
28	32	09	25	13	10	-20	28	10	40	26	60	38	64	41	57	34	46	24	45	19	17	06	18	-05	28
29	23	-03			06	-16	22	03	34	20	60	35	65	40	60	35	50	28	34	15	23	00	06	-06	29
30	26	08			12	-06	25	06	32	14	68	37	59	42	64	38	49	28	46	22	12	-15	25	-04	30
31	29	05			27	04			41	25			57	35	68	37			47	24			31	05	31
MONTHLY EXTREMES	33	-29	32	-17	40	-20	50	-07	55	08	68	14	68	32	70	28	68	20	62	-05	54	-15	41	-12	
AVE	20	1	20	-1	27	6	33	12	42	21	50	29	61	37	61	38	54	32	45	21	30	7	25	5	AVE

ANNUAL MEAN TEMPERATURE = 28

MAXIMUM = 70, AVERAGE MAXIMUM = 39 MINIMUM = -29, AVERAGE MINIMUM = 17

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM TEMPERATURES ARE IN DEGREES FAHRENHEIT

Daily New Snowfall and Total Snowdepth

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1963

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	0.0	17	4.0	37	1.0	54	0.0	48	0.0	33	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.0	6	0.0	8	1
2	0.0	17	13.0	46	4.0	56	0.0	46	1.5	35	T	0	0.0	0	0.0	0	T	0	0.0	0	0.0	5	0.0	8	2
3	0.0	17	T	43	3.0	56	6.0	52	T	33	T	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	0.0	8	3
4	4.0	21	0.0	42	4.0	56	0.0	50	0.0	32	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	5	0.0	8	4
5	2.0	23	0.0	41	1.0	55	0.0	49	0.0	31	T	0	0.0	0	0.0	0	0.0	0	0.0	0	5.0	9	0.0	8	5
6	0.0	22	0.0	40	1.0	56	0.0	48	0.0	30	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	T	8	0.0	8	6
7	1.0	23	0.0	39	T	54	0.0	47	0.0	27	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	8	2.0	10	7
8	0.0	21	0.0	39	T	53	0.0	46	0.0	25	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	T	7	1.0	10	8
9	0.0	19	0.0	38	0.0	53	2.0	46	0.0	24	5.0	5	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	0.0	10	9
10	0.0	19	0.0	38	0.0	52	T	45	0.0	22	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	4.0	14	10
11	4.0	21	2.0	39	T	52	T	45	0.0	20	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	1.0	14	11
12	T	21	0.0	39	2.0	55	0.0	44	0.0	18	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	2.0	14	12
13	0.0	22	0.0	38	3.0	55	0.0	42	0.0	17	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	2.0	14	13
14	2.0	22	0.0	38	T	54	0.0	40	0.0	15	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	T	5	T	14	14
15	1.0	22	2.0	40	T	53	0.0	39	0.0	13	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	3.0	17	15
16	T	22	2.0	42	5.0	57	1.0	38	0.0	10	4.0	4	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	2.0	17	16
17	3.0	24	1.0	42	T	57	0.0	37	T	8	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	4.0	9	T	15	17
18	3.0	24	2.0	44	2.0	58	1.0	39	0.0	4	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	T	14	18
19	3.0	26	3.0	45	3.0	60	1.0	39	0.0	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	0.0	14	19
20	2.0	27	5.0	47	T	60	0.0	39	T	0	0.0	0	0.0	0	0.0	0	0.0	0	T	T	0.0	7	0.0	14	20
21	5.0	28	8.0	51	0.0	58	0.0	37	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.0	2	0.0	7	3.0	16	21
22	4.0	29	T	50	T	55	3.0	39	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	4.0	9	2.0	17	22
23	1.0	29	1.0	49	0.0	53	0.0	37	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	T	17	23
24	0.0	27	2.0	52	0.0	53	0.0	35	T	0	0.0	0	0.0	0	0.0	0	0.0	0	T	T	0.0	8	0.0	17	24
25	5.0	32	3.5	51	2.0	54	0.0	35	T	0	0.0	0	0.0	0	0.0	0	0.0	0	T	T	2.0	10	0.0	17	25
26	8.0	36	2.5	52	0.0	52	0.0	33	T	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	0.0	17	26
27	1.0	36	4.0	55	0.0	52	4.0	35	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	2.0	19	27
28	0.0	36	2.0	55	0.0	51	3.0	36	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	5.0	23	28
29	T	36			4.0	53	3.0	39	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	11.0	31	29
30	4.0	36			0.0	50	T	35	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	1.0	29	30
31	5.0	36			0.0	48			0.0	0			0.0	0	0.0	0			6.0	6			0.0	26	31
TOT	58.0		57.0		35.0		24.0		1.5		9.0		0.0		0.0		0.0		8.0		18.0		41.0		TOT
MAX	8.0	36	13.0	55	5.0	60	6.0	52	1.5	35	5.0	5	0.0	0	0.0	0	0.0	0	6.0	6	5.0	10	11.0	31	MAX
MIN		17		37		48		33		0		0		0		0		0		0		4		8	MIN
AVE		26		44		54		41		13		0		0		0		0		0		7		15	AVE

TOTAL SNOWFALL = 251.5 INCHES. GREATEST 24 HOUR SNOWFALL = 13.0 INCHES. MAXIMUM SNOWDEPTH ON THE GROUND = 60 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 81, 6 INCHES = 6, 12 INCHES = 1

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1964

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	0.0	25	0.0	29	1.0	44	0.0	60	2.0	62	1.0	28	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0	13	1
2	0.0	23	3.0	33	0.0	43	5.0	65	T	60	5.0	32	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	7.8	21	2
3	6.0	28	1.0	32	6.0	49	7.0	70	5.0	64	1.0	30	0.0	0	0.0	0	0.0	0	0.0	0	3.2	4	2.1	22	3
4	T	26	T	32	1.0	48	2.0	69	T	62	2.0	31	0.0	0	0.0	0	0.0	0	0.0	0	T	3	1.4	22	4
5	1.0	26	0.0	31	2.0	48	3.0	68	0.0	60	T	28	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	1.2	22	5
6	T	26	3.0	34	4.0	52	5.0	69	0.0	60	T	26	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.4	21	6
7	2.0	27	1.0	34	2.0	52	1.0	70	T	59	0.0	25	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.0	20	7
8	4.0	29	1.0	34	3.0	52	4.0	72	3.0	60	T	24	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.0	20	8
9	T	28	1.0	34	0.0	51	T	69	T	59	T	23	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	T	20	9
10	T	27	4.0	37	2.0	52	0.0	65	0.0	58	0.0	20	0.0	0	0.0	0	0.0	0	T	0	T	T	4.0	23	10
11	2.0	29	T	36	1.0	52	1.0	65	4.0	61	T	18	0.0	0	0.0	0	0.0	0	T	T	2.5	3	4.0	24	11
12	1.0	29	1.0	36	0.0	51	5.0	67	2.0	60	T	16	0.0	0	0.0	0	0.0	0	0.0	0	5.0	5	7.0	27	12
13	0.0	29	1.0	36	2.0	52	6.0	71	0.0	57	0.0	13	0.0	0	0.0	0	0.0	0	0.0	0	2.2	6	0.6	24	13
14	0.0	29	2.0	36	2.0	53	4.0	72	T	55	T	12	0.0	0	0.0	0	0.0	0	0.0	0	7.6	12	0.0	23	14
15	0.0	28	1.0	37	T	52	0.0	69	0.0	53	T	9	0.0	0	0.0	0	T	T	0.0	0	5.8	16	1.2	23	15
16	T	28	T	37	2.0	54	0.0	66	0.0	50	0.0	6	0.0	0	0.0	0	T	T	0.0	0	0.4	14	0.0	20	16
17	1.0	27	1.0	37	0.0	52	0.0	64	0.0	48	0.0	3	0.0	0	0.0	0	0.0	0	0.7	1	0.2	13	2.4	21	17
18	1.0	27	5.0	41	0.0	51	0.0	62	0.0	46	T	T	0.0	0	0.0	0	0.0	0	T	0	0.2	13	0.0	21	18
19	4.0	30	2.0	42	8.0	59	2.0	63	0.0	44	0.0	0	0.0	0	0.0	0	1.6	1	0.0	0	4.1	16	3.0	24	19
20	1.0	28	6.0	47	2.0	58	T	61	0.0	42	0.0	0	0.0	0	T	T	1.6	1	0.0	0	2.0	16	0.1	24	20
21	0.0	27	T	46	0.0	57	4.0	65	0.0	41	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	16	T	23	21
22	1.0	27	1.0	45	0.0	55	2.0	64	0.0	39	T	T	0.0	0	0.0	0	T	T	0.0	0	0.0	15	2.0	22	22
23	2.0	29	1.0	45	1.0	55	0.0	60	0.0	38	T	T	0.0	0	0.0	0	0.0	0	0.7	1	T	14	0.0	22	23
24	1.0	29	0.0	45	4.0	58	0.0	59	0.0	36	0.0	0	0.0	0	0.0	0	0.0	0	3.0	3	2.0	16	11.0	32	24
25	1.0	29	2.0	46	4.0	60	4.0	62	0.0	34	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	T	14	10.0	40	25
26	T	29	T	45	4.0	60	1.0	61	0.0	31	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.4	13	9.0	44	26
27	5.0	32	1.0	45	8.0	67	8.0	70	T	29	0.0	0	0.0	0	1.0	1	1.2	1	0.0	T	6.0	18	3.0	42	27
28	0.0	31	T	45	2.0	67	3.0	69	T	28	0.0	0	0.0	0	T	0	0.0	0	0.0	T	1.4	17	8.0	47	28
29	0.0	30	0.0	44	0.0	65	1.0	65	0.0	27	0.0	0	0.0	0	0.5	0	0.0	0	0.0	T	1.2	16	2.0	45	29
30	0.0	30			0.0	64	T	62	3.0	30	0.0	0	0.0	0	T	0	0.0	0	0.0	T	T	14	0.6	43	30
31	1.0	30			0.0	62			0.0	29			0.0	0	0.0	0			2.0	2			T	41	31
TOT	34.0		38.0		61.0		68.0		19.0		9.0		0.0		1.5		4.4		6.4		45.2		80.8		TOT
MAX	6.0	32	6.0	47	8.0	67	8.0	72	5.0	64	5.0	32	0.0	0	1.0	1	1.6	1	3.0	3	7.6	18	11.0	47	MAX
MIN		23		29		43		59		27		0		0		0		0		0		1		13	MIN
AVE		28		39		55		66		48		13		0		0		0		0		12		27	AVE

TOTAL SNOWFALL = 367.3 INCHES. GREATEST 24 HOUR SNOWFALL = 11.0 INCHES. MAXIMUM SNOWDEPTH ON THE GROUND = 72 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 120. 6 INCHES = 16. 12 INCHES = 0

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1965

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	3.0	42	8.0	66	3.0	62	0.0	81	0.0	68	T	51	0.0	0	T	0	0.0	0	T	6	0.0	T	0.0	18	1
2	2.0	43	T	64	1.2	62	3.0	80	0.0	66	2.0	53	0.0	0	0.0	0	0.0	0	0.0	3	0.0	0	0.0	18	2
3	0.0	41	0.0	61	0.2	62	3.0	80	0.0	66	0.0	50	0.0	0	0.0	0	0.0	0	0.0	1	0.0	0	0.0	17	3
4	0.0	40	0.0	60	0.5	62	1.0	80	0.0	64	0.0	49	0.0	0	0.0	0	T	T	0.0	T	0.0	0	0.0	17	4
5	0.0	39	0.0	59	0.0	61	8.0	86	2.0	66	9.0	58	0.0	0	0.0	0	0.0	0	0.0	T	0.0	0	0.0	17	5
6	0.0	37	T	58	0.0	60	2.0	84	0.8	64	3.0	58	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	17	6
7	T	36	3.0	60	0.0	60	T	82	0.0	63	0.8	53	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	17	7
8	0.3	36	3.0	63	0.0	60	2.0	81	0.7	64	T	50	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	17	8
9	0.4	36	2.5	64	T	60	0.0	79	6.0	70	0.0	48	0.0	0	0.0	0	0.0	0	0.0	0	0.5	1	0.0	17	9
10	4.0	40	2.0	63	6.0	65	3.0	81	1.0	66	T	47	0.0	0	0.0	0	0.0	0	0.0	6	T	T	0.5	16	10
11	1.6	39	0.5	60	4.0	67	6.0	86	2.0	67	T	44	0.0	0	0.0	0	T	T	0.0	0	0.0	T	6.0	21	11
12	12.0	51	0.2	60	0.5	64	1.5	84	0.0	63	0.5	44	0.0	0	0.0	0	0.5	1	0.2	0	18.0	16	4.0	24	12
13	1.4	48	0.2	60	7.0	71	0.8	82	0.0	62	1.2	44	0.0	0	0.0	0	0.0	0	0.0	0	6.0	16	T	23	13
14	7.0	52	3.0	63	6.0	75	0.0	81	1.6	62	0.0	41	0.0	0	0.0	0	0.0	0	0.0	0	0.5	12	3.0	24	14
15	1.8	49	4.0	64	7.0	77	0.3	81	4.0	66	0.0	40	0.0	0	0.0	0	0.0	0	0.0	0	2.0	12	0.8	24	15
16	0.4	47	0.6	64	0.0	77	0.0	79	T	65	T	38	0.0	0	0.0	0	0.0	0	0.0	0	0.5	9	1.0	24	16
17	0.0	46	0.0	62	7.0	77	0.0	78	0.0	61	0.0	36	0.0	0	0.0	0	1.0	1	T	0	1.5	10	0.5	24	17
18	0.0	45	0.0	61	5.0	77	5.0	84	0.0	60	0.0	32	0.0	0	0.0	0	0.4	1	3.0	3	0.5	9	0.0	24	18
19	0.0	45	0.0	60	T	77	2.0	82	0.0	60	0.0	30	0.0	0	0.0	0	1.7	2	1.5	4	T	8	0.0	24	19
20	0.0	45	0.0	59	1.3	75	0.0	80	T	58	0.0	28	0.0	0	0.0	0	2.8	3	1.0	4	T	8	T	22	20
21	0.0	44	0.0	58	1.5	75	0.0	77	0.0	56	0.0	24	0.0	0	0.0	0	4.0	4	0.0	3	9.0	16	0.0	22	21
22	4.0	48	0.0	58	2.2	75	0.0	74	T	55	0.0	21	0.0	0	0.0	0	1.0	3	0.0	2	0.5	12	0.0	22	22
23	1.5	46	5.0	62	8.0	82	0.0	72	0.0	52	0.0	19	T	0	0.0	0	0.9	3	0.0	T	1.0	12	T	21	23
24	0.2	47	1.0	60	7.0	85	T	70	0.9	52	0.0	17	0.0	0	0.0	0	T	1	0.0	T	3.5	13	6.0	27	24
25	8.0	51	T	60	7.0	88	T	70	T	52	T	13	0.0	0	0.0	0	0.0	0	0.0	T	2.0	14	0.0	24	25
26	1.8	49	0.0	60	1.4	84	3.0	73	8.0	60	T	12	T	0	0.0	0	0.5	T	0.0	T	13.0	24	T	22	26
27	0.9	49	0.0	59	8.0	89	9.0	82	5.0	65	T	9	0.0	0	0.0	0	0.0	0	0.0	T	3.0	22	1.5	23	27
28	4.2	51	1.8	60	5.0	90	T	78	7.0	63	0.0	6	0.0	0	0.0	0	0.0	0	1.0	T	1.8	21	0.0	23	28
29	6.5	55			3.0	89	0.0	72	0.0	58	0.0	0	0.0	0	0.0	0	7.0	7	0.0	T	0.0	20	0.0	20	29
30	10.0	63			1.0	87	0.0	70	0.0	54	0.0	0	0.0	0	0.0	0	6.0	9	0.0	T	0.0	19	3.5	22	30
31	4.3	63			0.0	84			0.0	53			0.0	0	0.0	0			0.0	T			6.0	24	31
TOT	75.3		34.8		92.8		49.6		39.0		16.5		0.0		0.0		25.8		6.5		63.3		32.8		TOT
MAX	12.0	63	8.0	66	8.0	90	9.0	86	8.0	70	9.0	58	0.0	0	0.0	0	7.0	9	3.0	6	18.0	24	6.0	27	MAX
MIN		36		58		60		70		52		0		0		0		0		0		0		16	MIN
AVE		46		61		74		79		61		34		0		0		1		1		10		21	AVE

TOTAL SNOWFALL = 436.4 INCHES. GREATEST 24 HOUR SNOWFALL = 18.0 INCHES. MAXIMUM SNOWDEPTH ON THE GROUND = 90 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 102. 6 INCHES = 31. 12 INCHES = 3

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1966

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	1.0	24	6.0	34	0.0	44	0.0	41	0.0	41	T	T	0.0	0	0.0	0	T	T	T	T	8.0	6	0.0	10	1
2	1.0	25	2.5	36	T	42	T	39	0.0	40	0.0	0	0.0	0	0.0	0	T	T	0.0	0	0.0	4	0.0	10	2
3	0.0	24	1.0	36	1.0	44	0.5	43	0.0	38	0.0	0	0.0	0	0.0	0	0.0	0	7.0	7	0.0	3	0.0	10	3
4	0.0	23	0.0	35	1.0	43	4.5	45	0.0	36	0.0	0	0.0	0	0.0	0	0.0	0	5.0	7	T	2	1.5	11	4
5	0.0	23	0.0	35	0.0	42	3.0	45	0.0	33	T	T	0.0	0	0.0	0	0.0	0	0.0	2	0.5	2	T	11	5
6	0.0	23	0.0	34	0.0	42	0.5	44	0.0	31	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	10.0	21	6
7	T	23	0.5	34	0.0	42	0.0	43	0.0	29	0.0	0	0.0	0	0.0	0	0.0	0	T	T	0.0	2	7.5	27	7
8	0.0	23	4.0	36	0.0	42	0.0	42	0.0	27	6.0	6	0.0	0	0.0	0	0.0	0	0.0	0	T	2	4.0	29	8
9	T	23	6.0	41	0.5	42	0.5	41	0.5	26	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	12.0	15	1.5	27	9
10	0.0	22	2.0	40	0.0	42	0.0	40	2.5	28	T	T	0.0	0	0.0	0	0.0	0	0.0	0	5.0	17	0.0	26	10
11	0.0	22	1.5	40	5.0	47	5.0	44	0.5	27	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.5	12	2.0	26	11
12	5.0	25	0.5	40	0.0	44	8.5	52	3.0	29	0.0	0	0.0	0	0.0	0	0.0	0	T	T	0.5	12	2.0	26	12
13	1.5	26	3.5	43	0.0	42	0.2	48	2.5	32	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	T	12	0.0	24	13
14	2.5	27	1.5	42	0.0	42	1.0	47	0.5	30	0.0	0	0.0	0	0.0	0	0.0	0	12.0	12	0.0	10	0.0	24	14
15	5.0	30	1.5	42	0.0	42	0.0	45	0.0	28	0.0	0	0.0	0	0.0	0	1.0	1	1.0	6	0.0	10	1.5	24	15
16	2.7	30	2.5	42	0.0	41	0.0	42	0.0	27	0.0	0	0.0	0	0.0	0	T	T	0.0	4	0.0	9	0.0	24	16
17	0.0	29	1.5	43	6.0	45	T	41	0.0	24	0.0	0	0.0	0	0.0	0	T	0	2.0	5	0.0	8	0.0	22	17
18	0.0	29	0.5	42	3.0	45	4.5	46	0.0	24	0.0	0	0.0	0	0.0	0	0.0	0	T	4	T	8	0.0	22	18
19	0.0	28	0.0	42	0.0	44	4.5	48	0.0	22	0.0	0	0.0	0	0.0	0	0.0	0	T	3	0.0	7	0.0	22	19
20	T	28	0.5	42	0.0	43	4.0	50	0.0	18	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.0	7	0.0	22	20
21	2.0	29	2.0	44	1.0	44	T	48	0.0	17	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.0	7	0.0	21	21
22	0.5	29	1.0	44	7.5	47	0.5	47	T	13	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.0	7	1.0	22	22
23	T	29	T	42	1.5	47	5.0	52	1.0	11	0.0	0	0.0	0	0.0	0	0.0	0	T	2	0.0	7	1.0	22	23
24	2.0	30	0.0	42	0.0	46	1.0	48	0.0	8	0.0	0	0.0	0	0.0	0	0.0	0	0.5	2	0.0	7	0.0	21	24
25	2.5	31	0.0	42	0.0	46	0.0	46	0.0	5	0.0	0	0.0	0	0.0	0	T	T	0.0	2	0.0	7	0.0	21	25
26	T	31	1.0	43	0.0	44	0.0	44	0.0	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	3.0	9	0.0	21	26
27	0.0	31	2.0	44	0.0	44	3.5	47	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	2.0	10	T	21	27
28	0.0	31	3.0	46	0.0	43	0.5	45	T	T	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.0	10	1.5	22	28
29	T	31			0.0	42	0.0	43	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.5	9	0.5	22	29
30	0.0	31			0.0	42	0.0	42	0.0	0	0.0	0	0.0	0	0.0	0	T	T	0.0	T	1.5	10	0.2	22	30
31	0.2	31			0.0	41			0.0	0			0.0	0	0.0	0			T	T			1.0	23	31
TOT	25.9		44.5		26.5		46.2		10.5		6.0		0.0		0.0		1.0		27.5		34.5		35.2		TOT
MAX	5.0	31	6.0	46	7.5	47	8.5	52	3.0	41	6.0	6	0.0	0	0.0	0	1.0	1	12.0	12	12.0	17	10.0	29	MAX
MIN		22		34		41		39		0		0		0		0		0		0		2		10	MIN
AVE		27		40		43		45		22		0		0		0		0		3		8		21	AVE

TOTAL SNOWFALL = 257.8 INCHES. GREATEST 24 HOUR SNOWFALL = 12.0 INCHES. MAXIMUM SNOWDEPTH ON THE GROUND = 52 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 75. 6 INCHES = 12. 12 INCHES = 2

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1967

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	1.0	24	5.5	46	0.0	54	0.0	54	6.5	59	2.5	30	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	T	18	1
2	2.0	24	T	45	0.0	53	0.0	54	T	57	0.0	27	0.0	0	0.0	0	0.0	0	0.0	0	13.0	21	6.0	24	2
3	1.0	24	0.0	44	0.0	52	0.0	53	5.0	62	0.0	24	0.0	0	0.0	0	0.0	0	0.0	0	4.0	22	0.0	23	3
4	10.0	34	0.0	42	0.0	52	0.0	51	T	59	0.0	21	0.0	0	0.0	0	0.0	0	0.0	0	0.0	16	0.0	22	4
5	T	30	0.0	41	2.5	53	0.0	51	1.0	59	0.0	19	0.0	0	0.0	0	0.0	0	1.0	T	0.0	16	0.0	22	5
6	2.0	31	1.5	42	1.5	53	4.0	55	10.5	66	0.0	18	0.0	0	0.0	0	0.0	0	0.5	T	0.0	16	2.0	24	6
7	T	31	3.0	44	3.0	55	3.0	51	1.0	61	0.0	16	0.0	0	0.0	0	0.0	0	2.0	2	0.0	15	0.0	23	7
8	2.5	30	0.5	44	1.0	55	0.0	49	0.0	57	0.0	12	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	6.0	28	8
9	0.0	29	0.0	43	0.5	53	0.0	48	0.0	53	T	9	0.0	0	0.0	0	0.0	0	0.0	0	0.0	13	4.0	29	9
10	T	29	4.0	47	0.0	53	4.0	52	0.0	52	0.0	7	0.0	0	0.0	0	0.0	0	T	0	1.0	15	2.0	29	10
11	0.0	29	7.0	51	0.0	52	0.0	49	T	52	6.0	11	0.0	0	0.0	0	0.0	0	0.0	0	0.5	15	3.5	30	11
12	T	28	1.0	49	0.0	51	0.0	48	T	51	2.0	7	0.0	0	0.0	0	0.0	T	0.0	0	0.0	13	2.5	29	12
13	2.0	30	0.0	48	0.0	51	3.5	52	T	51	1.0	7	0.0	0	0.0	0	0.5	T	0.0	0	0.0	12	1.5	28	13
14	9.0	39	0.5	47	0.0	51	12.0	64	4.0	54	0.0	5	0.0	0	0.0	0	0.0	0	0.0	0	0.0	12	1.0	27	14
15	4.0	42	10.0	54	4.0	55	0.0	59	1.0	54	0.5	3	0.0	0	0.0	0	0.0	0	3.5	3	0.0	12	0.0	26	15
16	3.5	40	1.0	53	0.0	53	0.5	56	0.5	53	3.0	4	0.0	0	0.0	0	0.5	1	0.5	1	0.0	12	0.0	26	16
17	5.0	43	1.0	51	0.5	51	5.0	61	0.0	51	0.5	0	0.0	0	0.0	0	T	T	0.0	T	0.0	12	4.0	29	17
18	0.5	42	5.0	52	8.0	57	0.0	56	0.0	48	0.0	0	0.0	0	0.0	0	T	T	0.0	0	0.0	11	0.5	29	18
19	0.0	40	4.0	54	4.0	57	0.0	54	0.0	47	0.0	0	0.0	0	0.0	0	3.5	2	0.0	0	0.0	11	1.5	29	19
20	0.0	39	6.0	59	5.0	60	1.5	54	4.0	48	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.5	12	5.5	33	20
21	0.0	38	0.0	57	1.5	56	1.0	54	0.0	45	T	0	0.0	0	0.0	0	0.0	0	0.0	0	3.0	15	2.0	34	21
22	0.0	36	2.0	56	0.0	56	0.0	52	0.0	41	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	7.0	21	1.0	33	22
23	0.0	35	2.5	57	0.0	55	4.5	56	0.0	39	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	3.0	22	3.5	34	23
24	2.5	38	5.0	60	0.0	54	0.0	55	0.0	36	0.0	0	0.0	0	0.0	0	0.0	0	10.0	8	6.0	24	0.0	33	24
25	1.5	38	0.0	57	2.5	55	0.5	55	0.0	33	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	2.0	21	4.0	36	25
26	7.0	44	3.0	58	3.0	57	1.5	56	0.0	31	0.0	0	0.0	0	0.0	0	0.0	0	3.5	4	0.0	20	4.5	39	26
27	2.5	45	1.0	58	0.5	55	0.0	54	2.5	33	0.0	0	0.0	0	0.0	0	0.0	0	2.0	5	0.0	20	9.5	44	27
28	T	43	0.0	56	2.5	57	0.0	52	0.0	31	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	0.0	20	4.5	46	28
29	0.0	43			0.0	55	0.0	50	1.0	31	0.0	0	0.0	0	0.0	0	0.0	0	15.0	18	0.0	19	3.0	47	29
30	1.0	42			2.5	56	7.5	55	0.0	30	0.0	0	0.0	0	0.0	0	0.0	0	1.0	15	T	19	5.0	48	30
31	1.0	41			1.0	55			0.5	29			0.0	0	0.0	0			0.0	12			3.0	47	31
TOT	58.0		63.5		43.5		45.5		37.5		15.5		0.0		0.0		4.5		39.0		40.0		80.0		TOT
MAX	10.0	45	10.0	60	8.0	60	12.0	64	10.5	66	6.0	30	0.0	0	0.0	0	3.5	2	15.0	18	13.0	24	9.5	48	MAX
MIN		24		41		51		48		29		0		0		0		0		0		9		18	MIN
AVE		36		51		54		48		7		0		0		0		0		3		16		31	AVE

TOTAL SNOWFALL = 427.0 INCHES. GREATEST 24 HOUR SNOWFALL = 15.0 INCHES. MAXIMUM SNOWDEPTH ON THE GROUND = 66 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 112. 6 INCHES = 20. 12 INCHES = 3

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1968

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	1.0	47	5.0	45	T	68	0.0	60	0.0	65	0.0	51	0.0	0	0.0	0	0.0	0	T	T	T	T	T	21	1
2	2.0	46	T	45	0.0	66	3.0	62	0.0	62	0.0	48	0.0	0	0.0	0	0.0	0	T	0	1.0	1	1.5	22	2
3	3.0	46	1.0	44	2.0	66	7.0	67	T	62	0.0	45	0.0	0	0.0	0	5.0	5	T	0	0.0	0	1.0	23	3
4	1.0	46	3.5	46	0.0	64	3.0	68	0.0	60	0.0	42	0.0	0	0.0	0	5.5	6	0.0	0	T	T	T	22	4
5	0.0	45	T	46	0.0	63	1.0	67	T	60	0.0	39	0.0	0	0.0	0	T	1	3.0	2	3.0	3	0.0	21	5
6	1.0	45	0.0	45	0.0	61	T	64	T	58	0.0	36	0.0	0	0.0	0	0.0	0	T	0	1.5	4	0.0	21	6
7	0.0	44	0.0	43	0.0	60	2.0	65	3.0	59	0.0	34	0.0	0	0.0	0	0.0	0	0.0	0	3.0	6	0.0	21	7
8	0.0	44	0.0	43	2.5	62	2.5	67	T	58	T	32	0.0	0	0.0	0	0.0	0	T	0	0.0	5	0.0	21	8
9	0.0	44	T	43	4.0	65	T	66	T	58	T	30	0.0	0	0.0	0	0.0	0	6.5	6	3.0	8	0.0	21	9
10	0.0	44	0.0	42	1.0	65	0.0	65	2.0	59	T	29	0.0	0	0.0	0	0.0	0	0.0	2	9.5	14	0.0	20	10
11	2.0	44	0.0	42	1.5	65	0.0	63	3.5	61	1.5	29	0.0	0	0.0	0	0.0	0	0.0	1	0.5	13	0.0	20	11
12	2.0	45	3.0	44	T	64	0.0	62	T	58	0.0	27	0.0	0	0.0	0	0.0	0	0.0	T	0.0	13	3.0	22	12
13	0.0	43	0.5	44	0.0	62	0.5	62	1.5	59	0.0	24	0.0	0	0.0	0	0.0	0	0.0	0	T	11	2.0	24	13
14	0.0	43	1.0	44	8.0	70	1.5	63	T	58	0.0	21	0.0	0	0.0	0	0.0	0	0.0	0	1.5	12	0.0	23	14
15	0.0	43	5.0	48	6.5	72	0.0	62	6.5	64	T	18	0.0	0	0.0	0	0.0	0	0.0	0	3.5	14	0.0	22	15
16	0.0	42	2.0	49	T	69	T	61	T	59	0.0	15	0.0	0	0.0	0	5.0	5	1.0	1	2.0	14	0.0	22	16
17	0.0	41	1.5	50	T	67	T	61	3.0	61	0.0	13	0.0	0	0.0	0	4.0	4	4.0	5	10.0	21	1.5	23	17
18	1.0	42	4.0	54	1.0	67	3.0	64	2.0	63	0.0	12	0.0	0	0.0	0	T	3	T	4	1.0	20	4.5	27	18
19	0.0	41	2.5	55	0.5	67	1.0	63	T	60	0.0	8	0.0	0	0.0	0	0.0	0	0.0	2	1.0	18	0.5	27	19
20	0.0	41	1.0	54	2.0	67	7.0	70	3.0	63	0.0	4	0.0	0	0.0	0	0.0	0	0.0	T	T	17	0.0	27	20
21	0.0	41	5.5	57	3.0	69	0.0	66	2.0	63	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	16	2.5	28	21
22	0.5	41	5.5	60	2.0	69	6.0	70	0.0	60	0.0	0	0.0	0	0.0	0	0.0	0	T	0	0.0	16	2.5	29	22
23	1.0	42	11.6	69	T	68	2.0	71	0.0	57	0.0	0	0.0	0	0.5	T	0.5	T	0.0	0	4.0	16	T	28	23
24	0.0	41	7.0	70	0.0	66	0.0	68	0.5	57	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.5	19	0.0	28	24
25	0.0	41	2.5	70	0.0	66	2.5	69	3.5	59	T	0	0.0	0	0.0	0	0.0	0	0.0	0	2.0	20	0.0	27	25
26	0.0	41	0.0	66	T	65	7.0	74	4.0	61	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	3.0	22	1.0	28	26
27	0.0	41	1.5	65	3.0	66	2.5	71	3.5	61	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	1.5	29	27
28	2.0	42	11.0	74	0.0	63	1.0	71	T	58	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.0	21	T	29	28
29	0.0	41	2.0	70	0.0	63	0.0	69	0.0	56	0.0	0	0.0	0	0.0	0	2.0	1	0.0	0	2.5	23	0.5	28	29
30	0.0	40			0.0	61	0.0	66	0.0	54	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	22	3.0	30	30
31	0.0	40			0.5	60			1.5	54			0.0	0	0.0	0			0.5	T			4.0	30	31
TOT	16.5		76.6		37.5		52.5		39.5		1.5		0.0		0.5		22.0		15.0		55.5		28.5		TOT
MAX	3.0	47	11.6	74	8.0	72	7.0	74	6.5	65	1.5	51	0.0	0	0.5	0	5.5	6	6.5	6	10.0	23	4.5	30	MAX
MIN		40		42		60		60		54		0		0		0		0		0		0		20	MIN
AVE		43		53		65		66		60		19		0		0		1		1		14		25	AVE

TOTAL SNOWFALL = 345.6 INCHES. GREATEST 24 HOUR SNOWFALL = 11.6 INCHES. MAXIMUM SNOWDEPTH ON THE GROUND = 74 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 110. 6 INCHES = 13. 12 INCHES = 0

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM

T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT.

YEAR 1969

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	T	30	0.0	43	0.0	46	0.5	48	0.0	42	2.0	14	0.0	0	0.0	0	0.0	0	1.0	T	6.5	30	0.0	28	1
2	0.0	29	3.5	45	4.5	50	3.5	51	0.0	41	0.0	12	0.0	0	0.0	0	0.0	0	0.0	0	9.0	35	0.0	28	2
3	2.5	31	0.5	45	0.5	48	0.0	49	0.5	41	T	9	0.0	0	0.0	0	0.0	0	6.5	6	1.0	32	0.0	28	3
4	T	30	0.0	44	T	48	3.0	51	T	40	T	7	0.0	0	0.0	0	0.0	0	13.0	16	T	30	0.0	28	4
5	1.5	31	0.0	44	1.0	49	T	50	5.5	44	0.0	3	0.0	0	0.0	0	0.0	0	16.0	26	0.0	28	2.5	30	5
6	1.5	31	1.0	44	1.0	49	0.0	49	1.0	41	0.0	0	0.0	0	0.0	0	0.0	0	2.0	22	0.0	26	5.0	33	6
7	T	30	T	44	3.5	51	3.5	51	30.0	70	0.0	0	0.0	0	0.0	0	0.0	0	T	17	0.0	25	0.5	32	7
8	4.5	32	2.0	45	T	50	2.0	51	9.0	68	0.0	0	0.0	0	0.0	0	0.0	0	0.0	12	1.5	25	0.5	32	8
9	5.0	34	0.0	44	T	50	0.5	49	0.0	61	0.0	0	0.0	0	0.0	0	0.0	0	0.0	11	0.0	25	T	31	9
10	0.0	32	0.0	43	2.5	52	T	48	0.0	56	0.0	0	0.0	0	0.0	0	0.0	0	2.5	12	T	24	3.5	34	10
11	0.0	31	0.0	42	T	51	0.0	48	0.0	52	2.0	1	0.0	0	0.0	0	0.0	0	8.5	18	T	24	2.0	35	11
12	2.0	32	0.0	42	T	50	0.5	48	T	50	6.5	5	0.0	0	0.0	0	0.0	0	8.0	19	1.5	25	0.5	35	12
13	T	31	0.0	41	1.0	51	4.0	51	T	48	T	0	0.0	0	0.0	0	0.0	0	3.5	21	12.0	34	0.0	34	13
14	0.0	30	4.0	44	2.0	52	T	50	0.0	46	1.0	0	0.0	0	0.0	0	0.0	0	0.0	17	3.0	32	0.0	33	14
15	1.5	31	T	43	0.0	51	2.0	50	T	44	T	0	0.0	0	0.0	0	0.0	0	4.0	19	0.0	30	0.0	33	15
16	T	30	1.0	44	0.0	51	6.0	55	7.0	50	1.5	0	0.0	0	0.0	0	T	0	1.0	18	0.0	29	0.0	33	16
17	2.5	32	10.0	53	0.0	50	3.0	57	T	47	T	0	0.0	0	0.0	0	T	T	2.0	18	3.5	31	0.0	32	17
18	1.0	33	1.0	52	0.0	50	T	55	0.0	44	1.0	0	0.0	0	0.0	0	0.0	0	T	17	2.0	32	0.0	32	18
19	0.0	32	T	48	5.5	54	0.0	52	T	42	0.0	0	0.0	0	0.0	0	0.0	0	3.0	19	T	32	0.0	32	19
20	T	32	3.0	51	T	53	0.0	50	0.0	39	0.0	0	0.0	0	0.0	0	0.0	0	0.0	17	0.0	31	2.0	34	20
21	T	32	3.5	52	0.0	52	0.0	49	0.0	38	0.0	0	0.0	0	0.0	0	0.0	0	0.0	16	0.0	30	2.5	34	21
22	2.5	34	0.5	51	0.0	52	0.0	47	T	37	0.0	0	0.0	0	0.0	0	T	0	0.0	16	0.0	29	4.5	37	22
23	4.0	36	T	49	2.5	53	T	46	T	36	0.0	0	0.0	0	0.0	0	0.0	0	1.0	16	0.0	29	2.5	38	23
24	2.0	36	0.0	48	4.0	56	0.0	44	T	34	1.0	T	0.0	0	0.0	0	0.0	0	T	16	0.0	29	5.0	41	24
25	3.0	38	T	47	2.0	56	3.0	46	0.0	33	3.0	2	0.0	0	0.0	0	0.0	0	0.0	15	0.0	29	10.5	48	25
26	6.0	42	0.0	45	0.5	55	4.0	48	0.0	31	3.0	1	0.0	0	0.0	0	0.0	0	0.0	15	0.0	29	5.0	50	26
27	7.0	47	3.0	48	0.5	55	3.5	49	0.0	26	3.0	2	0.0	0	0.0	0	0.0	0	0.0	14	1.0	30	7.0	54	27
28	3.0	47	T	47	0.0	53	T	48	0.0	24	0.0	0	0.0	0	0.0	0	0.0	0	0.0	14	0.0	29	2.5	54	28
29	0.5	46			0.5	52	0.0	44	T	21	0.0	0	0.0	0	0.0	0	0.0	0	4.0	18	0.0	29	0.5	52	29
30	0.5	46			0.0	51	0.0	43	0.0	19	0.0	0	0.0	0	0.0	0	0.0	0	10.0	27	0.0	28	0.5	51	30
31	0.0	45			0.0	50			T	15			0.0	0	0.0	0			4.0	27			1.0	51	31
TOT	50.5		33.0		31.5		39.0		53.0		24.0		0.0		0.0		0.0		90.0		41.0		58.0		TOT
MAX	7.0	47	10.0	53	5.5	56	6.0	57	30.0	70	6.5	14	0.0	0	0.0	0	0.0	0	16.0	27	12.0	35	10.5	54	MAX
MIN		29		41		46		43		15		0		0		0		0		0		24		28	MIN
AVE		35		46		51		49		41		2		0		0		0		17		29		37	AVE

TOTAL SNOWFALL = 420.0 INCHES. GREATEST 24 HOUR SNOWFALL = 30.0 INCHES. MAXIMUM SNOWDEPTH ON THE GROUND = 70 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 104. 6 INCHES = 19. 12 INCHES = 4

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM

T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1970

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	1.5	51	1.0	62	T	66	1.0	80	4.0	83	0.5	27	0.0	0	0.0	0	0.0	0	0.0	T	4.0	16	T	31	1
2	0.0	51	2.0	63	1.0	67	1.0	79	1.0	81	T	26	0.0	0	0.0	0	0.0	0	0.0	T	1.5	15	0.0	30	2
3	T	49	1.5	63	4.5	70	5.0	84	0.0	78	0.0	24	0.0	0	0.0	0	0.0	0	0.0	T	2.0	16	3.0	31	3
4	2.0	48	9.0	71	1.5	70	6.0	87	0.0	76	T	22	0.0	0	0.0	0	0.0	0	0.0	T	T	15	0.0	29	4
5	1.0	48	4.0	71	1.0	69	0.0	84	0.0	74	T	19	0.0	0	0.0	0	T	T	0.0	T	0.0	14	0.5	29	5
6	T	48	T	68	4.0	71	0.0	83	0.0	73	0.0	17	0.0	0	0.0	0	0.0	0	0.0	T	T	13	0.0	29	6
7	1.0	47	T	67	T	68	0.0	79	T	72	0.0	14	0.0	0	0.0	0	T	T	1.0	1	0.0	12	0.0	29	7
8	T	47	T	66	0.0	67	T	78	0.0	71	T	12	0.0	0	0.0	0	0.0	0	3.0	3	9.0	20	0.0	28	8
9	T	47	0.0	65	1.0	67	0.0	77	1.5	72	T	9	0.0	0	0.0	0	0.0	0	1.5	4	2.0	19	0.0	28	9
10	1.5	48	0.0	64	3.5	69	0.0	77	2.0	72	1.0	8	0.0	0	0.0	0	0.0	0	9.0	13	0.0	19	2.0	26	10
11	4.5	52	0.0	63	0.5	68	T	76	0.0	69	5.0	12	0.0	0	0.0	0	0.0	0	9.0	17	7.0	23	7.5	33	11
12	1.5	52	1.0	63	3.5	70	3.5	78	0.0	66	8.0	20	0.0	0	0.0	0	0.0	0	0.0	12	T	22	2.0	34	12
13	1.5	52	4.5	67	1.0	70	2.5	80	0.0	64	T	16	0.0	0	0.0	0	T	T	0.0	7	7.0	28	0.0	34	13
14	0.5	52	6.5	73	8.0	76	2.0	80	T	63	0.0	11	0.0	0	0.0	0	0.0	0	0.0	5	4.0	29	0.0	34	14
15	T	51	1.0	71	1.5	72	1.5	79	1.5	64	0.0	8	0.0	0	0.0	0	0.0	0	6.0	11	T	27	2.0	35	15
16	1.5	52	T	69	4.0	76	0.5	79	0.0	61	0.0	6	0.0	0	0.0	0	0.0	0	0.0	9	0.0	24	1.0	34	16
17	9.0	57	0.0	65	0.5	74	1.0	78	0.0	58	0.0	2	0.0	0	0.0	0	0.0	0	0.0	6	4.0	28	0.0	32	17
18	7.0	61	4.5	68	5.5	77	6.0	83	0.0	56	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	2.0	27	3.0	35	18
19	1.0	59	0.5	68	2.5	77	2.5	83	0.0	53	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	7.0	32	3.0	36	19
20	9.0	62	0.0	66	0.0	76	9.5	91	0.0	52	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	1.0	30	T	35	20
21	7.5	66	0.0	65	0.5	75	1.0	89	0.0	48	0.0	0	0.0	0	0.0	0	0.0	0	3.5	9	0.0	27	2.5	36	21
22	1.0	63	0.0	65	4.0	78	8.0	93	T	45	0.0	0	0.0	0	0.0	0	16.5	16	T	9	2.0	26	2.0	36	22
23	2.0	62	0.0	64	0.5	77	0.5	90	T	42	0.0	0	0.0	0	0.0	0	0.0	11	4.0	12	15.0	40	4.0	38	23
24	0.0	60	1.0	65	0.0	75	1.0	89	0.0	40	0.0	0	0.0	0	0.0	0	0.0	4	T	10	2.0	36	1.5	37	24
25	7.5	65	7.0	72	11.5	84	0.0	87	T	38	0.0	0	0.0	0	0.0	0	18.0	18	2.5	11	T	35	2.0	37	25
26	1.0	62	1.5	71	T	82	0.0	84	T	36	0.0	0	0.0	0	0.0	0	T	12	3.0	12	1.5	34	0.0	37	26
27	1.0	60	0.0	68	2.5	82	0.0	80	T	33	0.0	0	0.0	0	0.0	0	0.0	7	4.5	16	7.5	40	2.0	38	27
28	6.0	65	0.0	67	0.0	80	2.5	80	T	31	0.0	0	0.0	0	0.0	0	0.0	4	0.0	14	T	37	1.0	38	28
29	3.0	65			2.0	82	3.0	81	T	30	0.0	0	0.0	0	0.0	0	0.0	1	0.0	12	0.0	35	2.0	40	29
30	T	64			2.0	80	2.0	81	1.0	29	0.0	0	0.0	0	0.0	0	0.0	T	0.0	12	0.0	32	5.0	42	30
31	0.0	63			0.5	80			1.0	27			0.0	0	0.0	0			0.0	12			1.0	42	31
TOT	71.5		45.0		67.0		60.0		12.0		14.5		0.0		0.0		34.5		47.0		78.5		47.0		TOT
MAX	9.0	66	9.0	73	11.5	84	9.5	93	4.0	83	8.0	27	0.0	0	0.0	0	18.0	18	9.0	17	15.0	40	7.5	42	MAX
MIN		47		62		66		76		27		0		0		0		0		1		12		26	MIN
AVE		56		67		74		82		57		8		0		0		3		9		26		34	AVE

TOTAL SNOWFALL = 477.0 INCHES, GREATEST 24 HOUR SNOWFALL = 18.0 INCHES, MAXIMUM SNOWDEPTH ON THE GROUND = 93 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 129, 6 INCHES = 28, 12 INCHES = 3

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1971

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	T	40	T	47	1.5	65	5.0	72	0.0	67	0.0	50	0.0	0	0.0	0	0.0	0	0.0	0	3.0	11	1.0	27	1
2	3.5	43	T	47	T	65	0.0	72	0.0	66	0.0	48	0.0	0	0.0	0	0.0	0	5.0	5	2.5	10	0.0	26	2
3	T	42	T	47	0.5	65	0.5	71	0.0	64	0.0	46	0.0	0	0.0	0	0.0	0	1.5	4	1.5	11	1.0	26	3
4	T	42	7.0	53	1.0	66	3.5	74	0.0	61	T	44	0.0	0	0.0	0	4.5	4	0.0	T	0.0	10	1.0	26	4
5	0.5	42	4.0	54	7.0	72	0.0	72	1.0	61	0.0	42	0.0	0	0.0	0	2.0	2	0.0	T	0.0	9	1.0	27	5
6	T	42	3.5	55	2.0	71	0.0	72	T	61	0.0	40	0.0	0	0.0	0	0.0	T	0.0	0	1.0	10	2.0	28	6
7	T	42	1.0	54	T	70	0.0	70	0.0	60	0.0	38	0.0	0	0.0	0	0.0	T	0.0	0	0.0	10	3.5	29	7
8	1.5	43	2.0	55	0.0	69	1.0	71	0.5	60	0.0	36	0.0	0	0.0	0	1.0	1	0.0	0	0.0	10	0.5	29	8
9	1.0	42	1.0	56	6.0	74	0.0	70	1.0	60	T	35	0.0	0	0.0	0	0.0	0	0.0	0	0.5	10	T	28	9
10	6.0	48	T	55	0.0	71	0.0	68	4.0	64	T	34	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	5.0	31	10
11	0.0	46	7.0	62	1.5	71	0.0	66	2.0	66	0.0	32	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	1.0	30	11
12	0.0	44	3.0	63	0.0	70	0.0	64	T	65	0.0	31	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	1.0	30	12
13	0.5	42	T	61	0.0	68	0.0	62	0.0	62	0.0	30	0.0	0	0.0	0	0.0	0	0.0	0	2.5	11	1.0	29	13
14	4.0	45	2.0	61	5.5	72	0.0	60	0.0	59	0.0	28	0.0	0	0.0	0	0.0	0	0.0	0	0.5	11	2.0	30	14
15	2.5	46	0.0	60	1.5	71	0.0	59	T	59	0.0	24	0.0	0	0.0	0	0.0	0	0.0	0	0.0	11	2.0	32	15
16	0.0	45	3.0	61	6.0	75	1.5	58	T	59	0.0	22	0.0	0	0.0	0	0.0	0	0.0	0	1.0	12	1.0	31	16
17	T	44	T	60	0.0	73	0.0	57	1.0	58	0.0	19	0.0	0	0.0	0	7.0	6	0.0	0	0.5	12	0.5	31	17
18	5.0	48	1.5	60	2.0	72	0.0	55	6.0	63	0.0	16	0.0	0	0.0	0	2.0	7	2.5	2	4.0	15	0.0	30	18
19	2.5	50	9.0	68	0.0	72	7.0	60	5.0	66	0.0	14	T	T	0.0	0	T	6	3.0	5	1.5	15	0.0	30	19
20	T	49	3.5	67	0.0	72	15.0	73	T	63	0.0	11	0.0	0	0.0	0	0.0	5	0.0	T	0.5	14	0.0	30	20
21	3.5	52	1.0	67	0.0	72	7.5	75	0.0	62	0.0	8	0.0	0	0.0	0	T	3	0.0	T	0.0	14	0.0	29	21
22	T	49	1.0	67	3.5	74	4.0	75	0.0	60	0.0	3	0.0	0	0.0	0	2.0	5	1.5	1	6.0	20	0.0	29	22
23	1.8	50	T	66	1.5	73	2.5	73	0.5	60	0.0	0	0.0	0	0.0	0	0.0	1	0.0	T	5.0	23	1.5	29	23
24	1.0	50	T	65	6.0	77	3.0	73	1.5	60	0.0	0	0.0	0	0.0	0	0.0	T	0.0	T	0.0	21	T	28	24
25	T	48	0.0	63	6.0	81	0.5	68	0.0	59	0.0	0	0.0	0	0.0	0	0.0	T	0.0	T	0.0	19	T	27	25
26	T	48	3.0	64	1.0	77	7.0	73	0.0	57	0.0	0	0.0	0	0.0	0	0.0	T	5.5	5	5.0	22	T	27	26
27	1.0	48	2.5	65	0.0	71	7.0	75	0.0	55	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	6.0	25	10.0	36	27
28	0.5	48	0.0	65	3.0	72	1.0	72	0.0	53	0.0	0	0.0	0	0.0	0	0.0	0	T	4	7.0	28	0.5	35	28
29	0.0	48			0.0	71	1.0	70	2.0	53	0.0	0	0.0	0	0.0	0	0.0	0	3.0	7	3.0	29	1.0	34	29
30	0.0	48			0.0	70	0.5	70	1.0	52	0.0	0	0.0	0	0.0	0	T	T	6.5	12	2.0	28	1.5	34	30
31	0.0	48			0.0	68			T	51			0.0	0	0.0	0			T	11			1.0	33	31
TOT	34.8		55.0		55.5		67.5		25.5		0.0		0.0		0.0		18.5		28.5		53.0		39.0		TOT
MAX	6.0	52	9.0	68	7.0	81	15.0	75	6.0	67	0.0	50	0.0	0	0.0	0	7.0	7	6.5	12	7.0	29	10.0	36	MAX
MIN		40		47		65		55		51		0		0		0		0		0		9		26	MIN
AVE		46		60		71		68		60		22		0		0		2		2		15		30	AVE

TOTAL SNOWFALL = 377.3 INCHES, GREATEST 24 HOUR SNOWFALL = 15.0 INCHES, MAXIMUM SNOWDEPTH ON THE GROUND = 81 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 116, 6 INCHES = 21, 12 INCHES = 1

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1972

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	0.0	33	0.0	39	3.0	54	4.0	65	0.0	58	0.0	24	0.0	0	0.0	0	0.0	0	0.0	0	7.0	13	T	26	1
2	1.5	31	1.5	40	1.0	54	T	65	0.0	57	0.0	22	0.0	0	0.0	0	0.0	0	0.0	0	4.0	15	0.0	25	2
3	5.0	33	T	40	5.0	56	3.0	66	0.0	57	0.0	19	0.0	0	0.0	0	0.0	0	0.0	0	1.0	14	0.0	24	3
4	T	33	0.0	39	13.0	67	0.0	65	0.0	56	0.0	16	0.0	0	0.0	0	T	T	0.0	0	0.0	12	T	24	4
5	1.5	33	0.0	39	15.0	74	1.0	64	0.0	54	0.0	14	0.0	0	0.0	0	0.0	0	0.0	0	T	11	7.0	31	5
6	1.0	33	3.0	42	0.0	70	0.0	61	1.0	55	0.0	10	0.0	0	0.0	0	0.0	0	0.0	0	2.0	12	1.0	30	6
7	0.0	33	3.0	44	T	68	2.0	62	T	55	0.0	6	0.0	0	0.0	0	T	T	0.0	0	1.0	12	0.5	29	7
8	0.0	33	2.0	44	0.0	67	0.0	61	2.0	57	0.0	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	11	0.5	29	8
9	1.5	34	T	44	0.0	66	0.0	60	0.0	54	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	5.0	15	2.0	30	9
10	0.5	31	4.0	45	0.0	61	0.0	59	T	53	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	15	2.0	31	10
11	6.0	36	0.5	45	0.0	58	0.0	58	1.5	54	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	13	0.0	30	11
12	2.0	31	1.0	45	0.0	57	3.0	59	1.5	55	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	13	0.5	30	12
13	9.0	38	T	44	0.0	56	1.5	58	2.5	57	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	4.0	17	1.0	30	13
14	1.5	36	4.0	45	0.0	55	3.0	60	2.0	59	T	T	0.0	0	0.0	0	0.0	0	0.0	0	T	16	1.0	30	14
15	0.5	36	4.0	48	3.0	58	2.0	60	0.0	55	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	0.0	30	15
16	0.0	36	5.0	51	T	57	0.5	58	0.0	53	0.0	0	0.0	0	0.0	0	0.0	0	1.0	1	4.0	18	0.0	30	16
17	0.0	36	11.0	59	0.0	56	0.0	56	0.0	51	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	T	16	0.0	30	17
18	0.0	36	4.0	58	0.0	55	0.0	55	0.0	50	0.0	0	0.0	0	0.0	0	0.0	0	1.5	1	0.0	15	0.0	30	18
19	0.0	35	0.0	55	2.0	56	0.0	55	0.5	49	0.0	0	0.0	0	0.0	0	0.0	0	T	T	2.5	16	1.0	30	19
20	2.0	36	0.0	52	2.0	58	0.0	54	1.0	47	1.5	1	0.0	0	0.0	0	1.0	1	0.0	T	0.5	16	3.0	33	20
21	T	36	0.0	51	1.0	57	2.0	56	0.0	44	T	T	0.0	0	0.0	0	T	T	5.0	5	0.5	16	1.5	34	21
22	2.5	35	0.0	51	0.0	56	2.0	57	0.0	43	0.0	0	0.0	0	0.0	0	0.0	0	3.0	6	T	16	0.5	33	22
23	3.0	35	2.0	51	0.0	54	0.0	56	1.0	44	0.0	0	0.0	0	0.0	0	T	T	1.0	6	0.0	15	3.0	36	23
24	3.5	36	2.0	53	7.0	61	0.0	55	T	42	T	T	0.0	0	3.0	3	0.0	0	0.0	5	0.0	15	1.0	37	24
25	T	35	6.0	57	T	58	0.0	53	0.0	39	0.0	0	0.0	0	T	T	0.0	0	0.0	4	2.0	16	1.0	36	25
26	1.0	35	3.0	57	0.0	55	8.5	60	0.0	37	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	3.0	18	T	36	26
27	3.5	38	1.0	56	3.0	58	12.0	68	0.0	34	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	13.0	31	0.0	34	27
28	2.0	39	0.0	54	3.0	60	5.0	69	0.5	33	0.0	0	0.0	0	0.0	0	2.0	2	3.0	5	3.0	31	0.0	34	28
29	4.0	40	0.0	53	2.0	60	0.0	62	0.0	31	0.0	0	0.0	0	0.0	0	3.0	4	T	4	2.0	28	1.5	35	29
30	0.0	40			2.0	62	1.0	58	0.0	29	0.0	0	0.0	0	0.0	0	T	T	1.0	5	1.0	27	5.0	39	30
31	0.0	39			4.0	64			0.0	27			0.0	0	0.0	0			0.5	5			1.0	39	31
TOT	51.5		57.0		66.0		50.5		13.5		1.5		0.0		3.0		6.0		16.0		57.5		34.0		TOT
MAX	9.0	40	11.0	59	15.0	74	12.0	69	2.5	59	1.5	24	0.0	0	3.0	3	3.0	4	5.0	6	13.0	31	7.0	39	MAX
MIN		31		39		54		53		27		0		0		0		0		0		11		24	MIN
AVE		35		48		60		60		48		4		0		0		0		2		17		31	AVE

TOTAL SNOWFALL = 356.5 INCHES, GREATEST 24 HOUR SNOWFALL = 15.0 INCHES, MAXIMUM SNOWDEPTH ON THE GROUND = 74 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 114, 6 INCHES = 12, 12 INCHES = 4

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

Q-12 PARK - ELEV. 11,314 FT. YEAR 1973

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	0.5	38	3.0	45	3.5	52	1.0	60	7.0	76	0.0	50	0.0	0	0.0	0	T	T	0.0	0	3.0	8	0.0	16	1
2	0.0	38	1.0	45	T	51	2.0	61	6.0	77	2.0	52	0.0	0	0.0	0	1.0	1	0.0	0	14.0	18	0.0	16	2
3	0.0	38	0.0	45	6.0	57	4.0	64	T	75	2.0	51	0.0	0	0.0	0	0.5	T	0.0	0	2.0	14	7.0	23	3
4	1.0	38	0.5	45	2.0	57	T	62	0.0	71	4.0	53	0.0	0	0.0	0	0.0	0	T	T	9.0	20	2.0	22	4
5	1.5	39	6.0	50	1.0	59	0.0	60	0.0	69	3.0	54	0.0	0	0.0	0	0.0	0	0.0	0	T	17	2.0	22	5
6	0.5	39	1.0	50	4.0	58	0.0	60	11.0	78	0.0	50	0.0	0	0.0	0	0.0	0	0.0	0	0.0	14	T	21	6
7	0.5	39	0.5	49	1.0	57	7.0	64	12.0	85	0.0	48	0.0	0	0.0	0	0.0	0	0.0	0	T	12	1.0	21	7
8	0.5	39	2.0	50	0.0	56	2.0	64	1.0	83	0.0	46	0.0	0	0.0	0	0.0	0	0.0	0	0.0	11	1.0	21	8
9	T	39	0.0	49	1.0	57	2.0	64	3.0	81	0.0	44	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	T	20	9
10	5.0	43	T	48	3.0	58	1.0	65	0.0	77	0.0	41	0.0	0	0.0	0	0.0	0	2.0	2	0.0	9	0.0	20	10
11	1.5	43	2.0	48	0.0	56	4.0	69	0.0	73	0.0	36	0.0	0	0.0	0	0.0	0	1.0	3	0.0	9	0.0	19	11
12	T	41	0.0	48	0.0	55	T	66	0.0	71	0.0	33	0.0	0	0.0	0	0.0	0	1.0	3	0.0	8	1.0	19	12
13	2.0	43	2.0	40	0.0	53	T	64	0.0	69	0.0	30	0.0	0	0.0	0	0.0	0	0.5	3	0.0	8	1.5	20	13
14	T	42	1.0	49	6.0	58	0.0	63	0.0	66	0.0	27	T	T	0.0	0	0.0	0	0.0	2	T	8	9.0	28	14
15	0.0	41	2.0	50	3.0	59	8.0	70	0.0	65	0.0	25	0.0	0	0.0	0	0.0	0	0.0	1	3.5	11	2.5	27	15
16	0.0	41	0.0	50	T	58	1.5	69	0.0	63	3.0	24	0.0	0	0.0	0	0.0	0	0.0	0	0.0	11	1.0	25	16
17	0.0	40	0.0	49	0.0	57	0.0	67	0.0	62	0.0	21	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	0.0	25	17
18	3.0	43	0.0	48	0.0	55	0.5	65	0.0	60	1.0	19	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	4.0	27	18
19	T	42	2.0	50	5.0	60	11.5	72	0.0	58	0.0	16	0.0	0	0.0	0	0.0	0	0.0	0	T	10	4.0	30	19
20	4.0	45	0.0	49	T	58	5.0	73	2.0	58	0.0	13	0.0	0	0.0	0	0.0	0	0.0	0	7.0	17	0.0	29	20
21	7.0	50	0.0	49	0.0	57	2.0	73	T	55	0.0	9	T	T	0.0	0	0.0	0	0.0	0	T	14	0.0	28	21
22	1.0	49	0.0	49	5.0	62	5.0	77	1.0	54	0.0	6	0.0	0	0.0	0	0.0	0	0.0	0	2.0	16	0.0	27	22
23	0.0	48	0.0	48	0.0	60	T	74	2.0	54	0.0	2	0.0	0	0.0	0	0.0	0	0.0	0	1.0	16	2.0	28	23
24	0.0	47	2.0	49	3.0	62	T	71	0.0	53	0.0	T	T	T	0.0	0	2.0	2	T	T	2.0	17	8.0	34	24
25	0.0	46	1.5	50	3.0	63	7.0	78	2.0	54	0.0	T	T	T	0.0	0	T	T	0.0	0	T	16	T	33	25
26	0.0	45	1.5	51	0.0	61	11.0	86	2.0	54	0.0	0	0.0	0	0.0	0	2.5	2	0.0	0	1.0	17	2.5	34	26
27	3.0	48	0.0	50	0.0	61	T	78	2.0	56	0.0	0	0.0	0	0.0	0	1.0	2	0.0	0	4.0	20	1.0	33	27
28	1.0	48	0.0	49	1.0	61	0.0	74	T	56	0.0	0	T	T	0.0	0	2.0	2	0.0	0	1.0	19	7.0	36	28
29	0.0	47			1.0	61	T	71	T	53	0.0	0	0.0	0	0.0	0	4.0	5	0.0	0	T	18	10.0	43	29
30	0.0	45			0.0	60	0.0	69	3.0	54	0.0	0	0.0	0	0.0	0	T	3	4.0	4	0.0	17	17.0	56	30
31	0.0	43			1.0	60			0.0	52			0.0	0	T	T			2.0	6			3.0	55	31
TOT	32.0		28.0		49.5		74.5		54.0		15.0		0.0		0.0		13.0		10.5		49.5		86.5		TOT
MAX	7.0	50	6.0	51	6.0	63	11.5	86	12.0	85	4.0	54	0.0	0	0.0	0	4.0	5	4.0	6	14.0	20	17.0	56	MAX
MIN		38		40		51		60		52		0		0		0		0		0		8		16	MIN
AVE		43		48		58		68		65		27		0		0		1		1		13		28	AVE

TOTAL SNOWFALL = 412.5 INCHES, GREATEST 24 HOUR SNOWFALL = 17.0 INCHES, MAXIMUM SNOWDEPTH ON THE GROUND = 86 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 119, 6 INCHES = 22, 12 INCHES = 3

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

G-12 PARK - ELEV. 11,314 FT. YEAR 1974

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	T	52	3.0	53	0.0	56	3.0	77	0.0	77	0.0	11	0.0	0	0.0	0	0.0	0	0.0	0	5.0	9	0.0	19	1
2	0.5	51	6.0	58	0.0	55	1.5	75	0.0	74	0.0	9	0.0	0	0.0	0	3.5	3	0.0	0	2.0	9	0.0	18	2
3	T	49	2.0	57	9.0	63	13.0	86	3.0	75	T	8	0.0	0	0.0	0	0.0	0	0.0	0	2.0	9	0.0	18	3
4	0.0	48	0.5	56	3.0	64	3.0	85	0.0	72	0.0	5	0.0	0	0.0	0	0.0	0	2.0	2	3.0	11	0.0	18	4
5	T	47	T	54	T	63	T	83	0.0	71	0.0	2	0.0	0	0.0	0	0.0	0	T	T	T	10	T	18	5
6	2.5	46	6.0	58	0.0	62	0.0	80	0.0	69	5.0	6	0.0	0	0.0	0	T	0	3.0	3	0.0	9	4.0	22	6
7	3.0	47	1.0	58	0.0	60	4.0	83	0.0	66	8.0	12	0.0	0	0.0	0	0.0	0	0.0	T	0.0	8	3.0	23	7
8	4.0	49	1.0	58	0.0	59	3.0	84	0.0	64	16.0	24	0.0	0	0.0	0	0.0	0	0.0	0	0.0	8	1.0	23	8
9	3.0	49	1.0	57	0.0	58	0.0	81	0.0	62	15.0	32	0.0	0	0.0	0	0.0	0	0.0	0	1.0	7	0.0	22	9
10	2.5	50	0.0	56	1.0	59	0.5	79	0.0	59	0.0	22	0.0	0	0.0	0	0.0	0	0.0	0	3.0	10	0.0	21	10
11	1.0	48	0.0	56	6.0	64	3.0	81	T	56	0.0	17	0.0	0	0.0	0	0.0	0	0.0	0	8.0	17	0.0	21	11
12	0.0	48	0.0	55	1.0	64	6.0	84	0.0	53	0.0	13	0.0	0	0.0	0	5.0	5	5.0	5	0.0	14	T	21	12
13	3.0	50	0.0	55	0.0	62	11.0	93	0.0	50	0.0	9	0.0	0	0.0	0	0.0	1	2.0	7	T	12	T	20	13
14	2.0	50	T	54	1.5	62	3.0	92	4.0	53	0.0	5	0.0	0	0.0	0	0.0	0	2.0	4	6.0	17	2.5	22	14
15	0.0	49	0.0	54	12.0	71	T	89	1.0	50	0.0	T	0.0	0	0.0	0	2.5	2	0.0	1	T	15	2.0	24	15
16	0.0	48	0.0	54	T	68	0.0	87	0.0	47	0.0	0	0.0	0	0.0	0	1.0	1	0.0	0	0.5	14	1.5	24	16
17	0.0	47	0.0	53	0.0	65	0.0	85	0.0	44	0.0	0	0.0	0	0.0	0	T	T	0.0	0	0.0	14	4.0	28	17
18	5.0	51	3.5	56	0.0	62	0.0	83	0.0	42	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	T	13	2.0	29	18
19	0.0	50	1.0	57	11.0	72	0.0	81	0.0	40	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	6.0	19	4.0	33	19
20	4.0	53	6.0	61	1.0	68	1.0	80	0.0	38	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	18	1.0	34	20
21	5.0	56	2.0	62	T	67	5.0	84	0.0	37	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	17	5.0	35	21
22	5.0	58	0.0	61	0.0	66	3.0	85	0.0	36	0.0	0	0.0	0	0.0	0	0.0	0	2.0	2	0.0	16	2.0	36	22
23	0.5	56	3.0	62	15.0	80	0.0	80	0.0	34	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	4.0	19	2.0	36	23
24	0.5	55	T	61	4.0	79	0.0	78	0.0	32	0.0	0	0.0	0	0.0	0	0.0	0	3.0	3	6.0	23	0.5	36	24
25	0.0	53	0.0	60	2.0	77	0.0	76	0.0	29	0.0	0	0.0	0	0.0	0	0.0	0	2.0	4	0.0	20	0.0	35	25
26	T	52	0.0	59	0.0	75	1.0	75	0.0	26	0.0	0	0.0	0	0.0	0	0.0	0	T	1	4.0	22	0.5	34	26
27	3.0	54	0.0	59	0.0	73	0.0	73	0.0	24	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.0	20	0.0	33	27
28	1.0	53	0.0	57	0.0	72	0.0	72	0.0	21	0.0	0	0.0	0	0.0	0	2.5	2	0.0	0	0.5	19	0.0	33	28
29	1.5	53			9.0	78	11.0	83	0.0	18	0.0	0	0.0	0	0.0	0	0.0	0	T	T	0.5	19	0.0	33	29
30	0.0	52			2.0	76	3.0	81	0.0	15	0.0	0	0.0	0	0.0	0	0.0	0	2.0	2	0.0	19	1.0	34	30
31	0.0	52			4.0	77			0.0	13			0.0	0	0.0	0			2.5	4			0.5	34	31
TOT	47.0		36.0		81.5		75.0		8.0		44.0		0.0		0.0		14.5		25.5		53.5		38.5		TOT
MAX	5.0	58	6.0	62	15.0	80	13.0	93	4.0	77	16.0	32	0.0	0	0.0	0	5.0	5	5.0	7	8.0	23	5.0	36	MAX
MIN		46		53		55		72		13		0		0		0		0		0		7		18	MIN
AVE		51		57		67		82		47		6		0		0		1		1		15		27	AVE

TOTAL SNOWFALL = 423.5 INCHES, GREATEST 24 HOUR SNOWFALL = 16.0 INCHES, MAXIMUM SNOWDEPTH ON THE GROUND = 93 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 108, 6 INCHES = 20, 12 INCHES = 5

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

G-12 PARK - ELEV. 11,314 FT. YEAR 1975

DAILY NEW SNOWFALL (NEW) AND TOTAL SNOWDEPTH ON THE GROUND (TOT) - INCHES

DAY	JAN NEW	JAN TOT	FEB NEW	FEB TOT	MAR NEW	MAR TOT	APR NEW	APR TOT	MAY NEW	MAY TOT	JUNE NEW	JUNE TOT	JULY NEW	JULY TOT	AUG NEW	AUG TOT	SEPT NEW	SEPT TOT	OCT NEW	OCT TOT	NOV NEW	NOV TOT	DEC NEW	DEC TOT	DAY
1	0.0	34	0.0	50	0.5	58	1.0	69	0.5	68	1.0	48	0.0	0	0.0	0	0.0	0	0.0	0	T	2	1.0	17	1
2	0.5	34	0.0	49	0.0	57	3.0	71	1.0	67	0.0	46	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	1.0	16	2
3	1.0	35	0.0	49	5.0	61	T	70	0.5	66	T	44	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0	16	3
4	0.0	35	0.0	49	2.0	63	0.0	67	0.0	64	0.0	41	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0	16	4
5	2.0	36	4.0	52	0.0	59	0.0	66	0.0	62	0.0	39	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.0	16	5
6	3.0	38	2.0	53	0.5	58	0.0	65	5.0	67	0.0	36	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.0	16	6
7	2.0	39	T	53	3.5	61	0.0	63	0.5	65	0.0	34	0.0	0	0.0	0	0.0	0	0.0	0	0.0	T	0.0	16	7
8	2.5	41	3.0	54	T	60	6.0	67	2.0	67	0.0	32	0.0	0	0.0	0	0.0	0	3.0	3	3.0	3	1.0	17	8
9	4.0	42	2.0	55	2.5	61	0.5	66	T	65	1.0	32	0.0	0	0.0	0	0.0	0	T	1	8.0	11	0.5	17	9
10	1.0	42	3.0	55	2.0	63	1.0	66	0.0	63	14.0	45	0.0	0	0.0	0	0.0	0	0.0	0	T	8	0.0	17	10
11	1.0	42	7.0	61	0.5	62	3.0	69	0.0	62	T	42	0.0	0	0.0	0	0.0	0	0.0	0	5.0	11	0.0	17	11
12	1.5	42	0.0	61	3.0	64	T	68	T	60	0.0	37	0.0	0	0.0	0	0.0	0	0.0	0	1.0	9	T	17	12
13	3.0	44	0.0	59	0.5	64	0.5	68	7.0	66	T	35	0.0	0	0.0	0	0.0	0	T	T	0.0	9	0.0	17	13
14	T	43	1.0	58	0.5	63	0.0	67	T	62	0.0	32	0.0	0	0.0	0	0.0	0	0.5	T	0.0	8	2.0	18	14
15	0.0	42	2.0	59	1.5	63	0.0	66	0.0	59	0.0	29	0.0	0	0.0	0	0.0	0	0.5	T	0.0	8	2.0	20	15
16	0.0	41	T	59	0.5	63	0.0	65	0.0	57	T	26	0.0	0	0.0	0	0.0	0	0.0	0	0.0	8	0.0	19	16
17	4.0	44	1.0	59	1.0	62	0.0	64	0.0	55	2.0	25	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	1.5	19	17
18	0.5	43	2.0	60	0.5	62	7.0	71	0.5	54	0.0	23	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	1.0	19	18
19	4.0	47	0.5	59	T	62	5.0	73	3.0	54	T	21	0.0	0	0.0	0	0.0	0	0.0	0	2.0	9	0.0	19	19
20	0.0	45	2.0	59	0.0	60	T	69	0.0	52	T	18	0.0	0	0.0	0	0.0	0	0.0	0	2.0	11	0.0	19	20
21	4.0	46	4.0	61	5.0	65	0.5	69	T	50	0.0	16	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	0.0	19	21
22	0.5	46	1.0	60	2.0	63	0.0	67	1.5	50	0.0	14	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	T	18	22
23	T	45	0.0	60	4.0	65	0.0	65	7.0	56	0.0	11	0.0	0	0.0	0	0.0	0	1.0	1	T	10	0.0	18	23
24	3.0	47	T	60	3.0	66	0.0	64	1.0	54	0.0	8	0.0	0	0.0	0	0.0	0	9.0	10	3.0	13	1.5	19	24
25	12.0	57	0.0	58	3.0	68	0.0	63	T	51	0.0	5	0.0	0	0.0	0	0.0	0	0.5	10	9.0	21	5.0	24	25
26	1.0	55	0.0	58	0.5	66	0.0	60	0.0	50	0.0	2	0.0	0	0.0	0	0.0	0	0.0	7	2.0	19	3.0	25	26
27	0.0	53	0.0	57	6.0	72	T	59	0.0	49	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	5.0	20	3.0	24	27
28	2.0	54	2.0	59	1.0	70	12.0	70	2.0	48	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	1.0	20	4.0	26	28
29	2.0	53			T	69	3.0	70	5.0	51	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	20	0.5	25	29
30	0.0	52			0.5	68	1.0	69	1.0	51	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	18	1.0	24	30
31	1.5	52			1.0	69			1.0	49			0.0	0	0.0	0			1.0	2			1.0	25	31
TOT	56.0		36.5		50.0		43.5		38.5		18.0		0.0		0.0		0.0		15.5		45.0		29.0		TOT
MAX	12.0	57	7.0	61	6.0	72	12.0	73	7.0	68	14.0	48	0.0	0	0.0	0	0.0	0	9.0	10	9.0	21	5.0	26	MAX
MIN		34		49		57		59		48		0		0		0		0		0		1		16	MIN
AVE		44		57		63		67		58		25		0		0		0		2		10		19	AVE

TOTAL SNOWFALL = 332.0 INCHES, GREATEST 24 HOUR SNOWFALL = 14.0 INCHES, MAXIMUM SNOWDEPTH ON THE GROUND = 73 INCHES
NUMBER OF DAYS 24 HOUR NEW SNOWFALL GREATER THAN OR EQUAL TO 1 INCH = 106, 6 INCHES = 12, 12 INCHES = 3

OBSERVATIONS ARE FOR THE 24 HOURS ENDING AT 8 AM T = TRACE

ailing Wind Direction and Mean Daily Windspeed

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1968

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	N	17	NE	3	W	4	NW	6	NW	6	NW	6	NE	3	NW	8	NW	12	E	1	N	7	1
2	M	M	N	7	S	4	W	7	NW	7	NW	6	NW	6	E	3	W	10	NW	11	NW	6	NW	14	2
3	M	M	N	7	N	3	NW	8	NW	6	W	6	NW	6	S	3	NW	4	NW	5	S	3	NW	14	3
4	N	5	NE	3	NE	3	NW	3	NW	7	W	6	W	6	N	5	NW	8	W	4	NW	9	M	26	4
5	N	10	E	3	NW	2	NW	7	NW	7	W	7	W	3	W	5	NW	7	NW	9	N	4	M	25	5
6	N	11	SW	3	NE	3	NW	12	NW	8	W	6	N	4	N	4	NW	9	NW	9	NW	6	M	17	6
7	E	3	NE	4	NW	8	NW	17	NW	21	NW	5	W	4	SW	3	NW	14	NW	7	E	4	M	5	7
8	E	6	NW	4	E	6	NW	6	NW	12	SW	6	E	4	NW	3	NW	8	M	M	N	8	M	11	8
9	E	4	E	3	NW	6	NW	6	W	7	NW	4	NW	4	NW	2	NW	5	NE*	3*	NW	20	M	4	9
10	E	4	E	3	SW	5	NE	4	W	5	NW	7	NW	6	SW	2	SW	4	NW	5	NW	11	M	5	10
11	N	8	N	6	NW	6	NW	5	W	5	NW	8	NW	4	NW	6	SW	5	NE	3	N	6	M	14	11
12	N	4	NE	5	N	5	NW	11	W	6	NW	9	N	5	NW	4	NW	4	NW	6	NW	12	M	26	12
13	N	7	NE	3	NW	15	NW	14	NW	12	NW	17	NW	5	NW	4	W	6	NW	9	E	3	M	7	13
14	N	8	NW	5	NW	12	NW	19	NW	12	NW	8	W	7	NW	7	W	8	NW	8	E	2	M	4	14
15	E	2	NW	9	NW	11	NW	15	NW	12	NW	10	N	5	NW	12	W	14	NW	9	E	9	M	8	15
16	E	3	NW	12	NW	9	NW	13	NW	7	NW	7	NW	8	NW	6	NW	12	NW	10	NW	24	M	5	16
17	N	7	NW	10	NW	11	SW	11	NW	12	NW	9	NW	6	NW	9	NW	10	NW	8	NW	12	M	4	17
18	SW	2	NW	14	NW	12	SW	10	NW	9	NW	9	N	4	NW	15	NW	11	NE	7	NW	9	M	5	18
19	N	2	NW	14	NW	5	NW	10	NW	7	W	5	W	5	NW	9	NE	6	W	6	E	3	M	4	19
20	NE	4	NW	9	N	4	N	6	NW	6	NW	11	NW	7	NW	5	W	9	NW	15	NW	7	M	5	20
21	NW	1	NW	11	NW	13	NW	7	NW	8	NW	5	NE	5	N	5	W	6	NW	9	E	2	M	6	21
22	E	5	NW	15	NW	12	E	6	NW	9	NW	6	NW	6	NW	5	SW	5	NW	15	NW	7	M	12	22
23	N	3	NW	16	E	4	NW	6	NW	6	NW	6	W	4	NW	16	NW	6	NW	21	NW	11	M	[illegible]	23
24	NE	2	NW	19	NW	12	NW	6	NW	4	NW	6	SW	4	NW	4	W	5	NW	8	NW	8	M	13	24
25	E	4	NW	14	NW	9	NW	8	NW	9	NW	8	W	6	NE	6	W	5	W	2	NW	10	M	15	25
26	E	5	NW	5	NW	17	NW	7	NW	11	NW	12	E	5	W	5	W	3	NW	7	SW	2	M	3	26
27	NE	5	NE	3	N	7	E	7	NW	14	NW	8	S	5	NE	4	NW	7	NW	23	W	3	M	7	27
28	NW	12	NW	8	NW	7	NW	7	NW	8	NW	10	W	6	NE	5	S	6	NW	10	E	3	M	13	28
29	N	5	NW	6	W	7	NW	4	NW	9	NW	13	N	4	NE	3	W	5	NW	3	N	3	M	17	29
30	N	9	M	M	NW	9	NW	7	NW	7	NW	11	N	5	NE	3	NW	8	E	4	N	2	M	28	30
31	N	12	M	M	NW	5	M	M	NW	7	M	M	W	5	S	4	M	M	E	5	M	M	M	25*	31
MONTH MAX	NW	12	NW	19	NW	17	NW	19	NW	21	NW	17	NW	8	NW	16	NW	14	NW	23	NW	24	M	28	MAX
AVE		06		08		08		08		09		08		05		05		07		08		07		11	AVE

YEARLY MAX -- M 28 MPH ON DEC 30

VAR - VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA

FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1969

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	21	M	12	SW	8	SW	6	M	12	M	9	M	11	W	8	N	4	W	12	E	3	E	1	1
2	M	14	M	19	E	5	NE	3	M	10	M	9	M	12	SW	6	W	4	W	9	SW	7	E	1	2
3	M	4	M	4	NE	3	SW	7	M	7	M	2	M	14	W	5	W	5	E	3	W	3	VAR	1	3
4	M	6	M	4	SE	5	W	5	M	5	M	3	M	7	N	5	W	9	E	3	SW	3	NW	6	4
5	M	20	M	8	SW	4	NE	4	M	8	M	6	M	6	W	5	W	10	W	6	E	2	E	1	5
6	M	33	NE	6	M	3	SW	12	M	10	M	6	M	7	M	9	SW	7	W	6	SW	3	W	5	6
7	M	30	W	8	M	5	SW	21	M	9	M	4	M	7	W	6	N	5	W	6	W	7	NW	7	7
8	M	17	SE	3	M	4	W	8	M	8	M	8	M	7	SW	9	E	4	E	8	E	3	NW	7	8
9	M	5	W	5	M	4	SE	6	M	11	M	6	M	3	SW	5	VAR	3	W	18	E	4	E	2	9
10	M	16	NW	11	M	2	SW	5	M	7	NE	5	NW	4	SW	6	E	3	E	4	W	10	W	16	10
11	M	10	W	8	M	5	SE	5	M	9	W°	5	W	6	W	6	NW	6	E	9	SW	12	W	14	11
12	M	5	SW	3	M	6	SW	2	M	9	SW	5	NE	3	W	6	E	6	E	3	SW	19	E	5	12
13	M	3	NE	4	SW	3	SW	3	M	5	SW	4	SE	5	E	3	W	9	W	9	SW	23	E	6	13
14	M	3	NE	5	SE	3	SW	6	M	4	SW	4	W	7	SW	6	E	3	W	12	SW	8	E	3	14
15	W	14	NE	4	SE	3	SE	5	M	5	NE	3	W	6	W	7	NE	3	SW	8	E	4	S	2	15
16	NW	11	NE	4	SE	3	N	2	M	3	S	4	NE	7	W	7	NE	3	E	4	E	8	E	2	16
17	NW	17	W	6	W	8	N	4	M	6	NE	1	NE	5	W	5	W	2	W	8	W	9	E	7	17
18	NW°	5	NE	3	W	13	SW	4	M	9	NE	3	NE	4	W	3	E	3	E	4	W°	10	E	1	18
19	E	4	SW	6	SW	18	M	6	M	10	NW	6	NE	M	NE	2	NW	4	E	7	M	3	W	6	19
20	NW	12	SW	5	SW	4	M	11	M	10	SW	9	W	M	NE	3	NW	3	E	2	W	4	NW	21	20
21	E	3	NW	5	W	8	M	M	M	7	W	12	SW	M	N	3	W	4	E	4	E	2	W	19	21
22	SW°	12	SW	5	NW	6	M	M	M	7	NW	8	W	M	E	3	SW	3	E	3	E	3	W	24	22
23	W	13	NE	4	W	10	M	M	M	5	SW	5	W	7°	W	4	NE	3	W	5		0	W	18	23
24	W	6	W	10	SW	6	SW	9	M	4	SW	8	W	5	W	2	W	10	E	2	W	4	NW	17	24
25	W	8	W	11	SW	11	W	15	M	5	M	24	SW	5	S	4	W	8	E	2	E	3	W	8	25
26	W	11	W	11	W	9	W	11	M	6	M	20	W	9	M	4	W	5	E	2	W	6	W	10	26
27	W	9	NW	10	W	13	NW	9	M	9	M	15	SW	5	M	5	W	6	E	4		0	E	2	27
28	SW	7	NE	4	SW	19	SW	6	M	8	M	15	W	6	M	3	W	8	W	5	E	1	E	1	28
29	M	12	M	M	W	13	W	12	M	5	M	7	E	5	E	3	W	5	W	8		0	E	1	29
30	M	12	M	M	NW	11	M	14	M	12	M	5	W	6	W	3	W	16	W	8	E	1	E	4	30
31	M	16	M	M	SW	16	M	M	M	8	M	M	W	5	S	4	M	M	W	7	M	M	NW	5	31
MONTH MAX	M	33	M	19	SW	19	SW	21	M	12	M	24	M	14	W	9	W	16	W	18	SW	23	W	24	MAX
AVE		12		07		07		07		08		07		06		05		05		06		06		07	AVE

YEARLY MAX -- M 33 MPH ON JAN 6

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1970

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	E	3	M	10	S	4	NW	10	W	4	NW	3	W°	7°	SW	7	W	6	NE	4	NW	6	W	11	1
2	NW	8	M	18	W	13	W	20	W	8	SE	5	W	5	SW	7	W	6	W	3	NW	5	W	16	2
3	W	16	M	17	W	7	VAR	4	W	5	E	5	S	7	VAR	5	W	15	W	5	NW	4	W	18	3
4	W°	13°	M	16	W	8	W	9	W	8	E	8	NW	7	E	4	W	7	W	3	NE	1	NW	6	4
5	M	M	W	13	M	M	W	13	SW	5	S	4	VAR	4	SE	3	SE	3	W	9	NW	5	NW	4	5
6	M		NW	8	M	M	NE	5	SW	7	SW	4	NW	3	VAR	3	W	14	W	7	NW	7	E	2	6
7	M	M	W	6	M	M	W	16	W	9	SW	4	SE	3	SE	2	W	9	SW	4	W	5	W	3	7
8	NW	6	W	5	M	M	NW	12	W	13	W	6	NE	4	W°	5	W	10	W	6	NW	14	W	18	8
9	E	3	E	2	M	M	NE	4	W	14	W	6	SW	3	M	4	W	12	W	8	W	4	W	8	9
10	NW	8	NW	5	M	M	W	14	W	12	E	7	W	4	M	6	W	11	W	7	W	12	NW	5	10
11	E	7	W	6	M	M	W	13	SW	10	NW	7	NE	5	M	6	W	21	W	4	W	5	W	7	11
12	W	7	W	9	NW	7	NW	15	W	11	NW	11	SW	4	NW°	6	W	14	W	3	NW	6	W	6	12
13	NW	6	W	15	W	14	S	4	W	9	SW	8	W	7	W	8	W	10	W	4	N	3	SW	3	13
14	E	4	NW	5	W	15	S	13	NW	8	SW	7	W	10	W	4	W	8	W	1	NW	5	E	3	14
15	E	5	W	6	W	3	W	15	W	11	W	9	W	8	E	2	W	7	SW	2	SW	1	NW	8	15
16	E	4	W	15	W	5	S	8	W	8	W	10	W	7	W	4	W	8	W	2	W	8	W	14	16
17	W	14	W	23	W	8	S	7	W	12	W	10	W	7	W	7	W	3	NE	4	NW	7	W	8	17
18	W	15	NW	13	NW	4	NW	16	SW	11	W	10	E	3	W	4	E	2	W	2	W	11	W	10	18
19	W	29	E	3	W	4	NW	20	SW	11	NW	6	S	4	SE	4	W	9	W	6	NW	13	W	8	19
20	W	19	E	2	W	3	NW	17	SW	10	SE	5	W	4	SW	3	W	14	W	6	W	15	W	2	20
21	W	21	E	3	W	8	S	6	SW	8	S	5	NW	4	W	3	SW	2	W	8	W	29	W	6	21
22	W	20	E	4	W	12	W	13	W	10	W	6	SW	4	M	M	W	5	NW	3	W	20	W	23	22
23	W	15	SW	4	W	17	NW	8	W	6	W	5	W	7	M	M	W	10	NW	4	NW	17	NW	4	23
24	W	23	E	2	W	24	W	10	W	6	W	8	NW	5	M	M	W	10	W	7	W	24	W	23	24
25	W	14	W	4	NW	12	W	10	M	7	W	13	W	7	M	M	W	5	W	11	W	20	E	4	25
26	W	16	NW	6	NE	5	W	14	M	7	W°	8°	SW	4	SW°	6°	W	3	NE	2	W	8	F	1	26
27	W	16	W	4	S	5	SW	8	W°	4	M	M	W	6	SW	6	NE	1	NW	7	W	7	W	13	27
28	W	16	W	3	NW	5	E	5	W	5	M	M	W	7	SW	6	NE	3	W	17	W	8	NW	9	28
29	W	14	M	M	SE	4	W	5	W	7	M	M	NW	6	NW	5	NE	1	W	21	W	7	W	8	29
30	E	1	M	M	SE	12	NE	3	W	9	M	M	W	10	S	8	NW	2	W	20	W	29	NW	19	30
31	E	3	M	M	W	4	M	M	W	5	M	M	SW	4	E	4	M	M	W	15	M	M	W	21	31
MONTH MAX	W	29	W	23	W	24	W	20	W	14	W	13	W	10	W	8	W	21	W	21	W	29	W	23	MAX
AVE		12		08		08		11		08		07		05		05		08		07		10		09	AVE

YEARLY MAX -- W 29 MPH ON JAN 19

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1971

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	W	8	NE	3	SE	5	W	18	M	7	M	7	SW	6	W	3	SW	5	M	10	W	13	M	3	1
2	SW	8	NW	3	NW	7	NW	12	NW	7	M	8	SW	10	SW	5	SW	6	M	11	W	19	VAR	1	2
3	S	8	NW	6	W	10	NW	11	W	7	S	7	W	7	W	3	SW	7	M	1	M	7	SW	2	3
4	NW	5	W	16	W	12	NW	9	SW	8	W	7	SW	11	NE	3	SW	16	M	2	W	16	SW	1	4
5	NW	8	W	21	NW	9	NW	9	NW	8	M	9	SW	8	NE	5	SW	11	M	1	W	18	E	5	5
6	NW	1	NW	16	W	15	NW	3	S	6	M	9	SW	11	NE	4	SW	3	M	2	W	7	SW	3	6
7	W	1	NW	16	NW	12	M	8	S	4	M	7	W	5	M	M	SW	8	M	4	NE	2	S	4	7
8	W	11	W	15	NE	4	NW	8	E	4	SW	7	S	6	M	M	SW	4	SW	2	W	8	E	3	8
9	W	18	NW	6	NW	9	SW	7	W	8	M	5	SW	6	M	M	W	4	SW	2	NE	4	E	3	9
10	W	22	W	18	W	13	W	15	W	4	M	4	SW	11	M	M	N	5	S	3	W	3	W	8	10
11	NW	13	NW	21	NW	7	W	19	SE	5	M	5	SW	11	NE	6	W	6	SW	7	E	4	W	5	11
12	NW	18	NW	8	NW	11	M	21	E	2	M	1	SW	15	S	4	SW	4	SW	8	NE	3	NE	4	12
13	W	20	NW	10	M	13	NE	5	NW	4	M	5	SW	7	NE	4	SW	8	SW	6	M	9	N	1	13
14	W	23	NW	8	M	20	M	8	M	7	M	11	SW	8	NE	7	SW	11	SW	10	NE	3	VAR	1	14
15	W	12	W	11	M	19	W	4	W	7	M	6	SW	6	M	4	M	7	SW	9	S	5	W	7	15
16	W	23	W	16	NW	16	W	9	M	13	M	9	N	5	SW	5	SW	10	S	6	SE	6	W	6	16
17	W	24	W	9	NW	14	SW	9	NW	4	M	12	SW	6	N	4	E	7	SW	6	NE	2	M	M	17
18	NW	15	W	8	NW	11	S	7	NW	4	M	11	NE	5	SW	2	SW	4	W	7	W	2	M	M	18
19	NW	7	E	5	NW	9	SE	9	W	13	M	5	S	2	SE	4	SW	7		0	NE	2	M	M	19
20	W	20	S	8	NW	11	NW	15	W	10	M	6	SW	3	NE	2	SW	5	VAR	1	NE°	2	M	M	20
21	W	19	NE	1	NW	13	NW	7	SW	7	M	5	W	5	E	3	S	4	NE	1	M	3	M	M	21
22	NW	19	E	1	NW	19	NW	3	W	8	M	11	N	3	E	4	M	M	NE°	1°	M	2	M	M	22
23	NW	8	E	3	M	17	SW	3	NW	4	SW	10	NE	4	NE	4	M	M	M	M	M	3	SW	19	23
24	W	18	NW	3	NW	15	W	7	W	12	W	11	M	6	NE	4	M	M	M	M	M	3	SW	11	24
25	W	26	W	13	NW	16	SE	9	W	8	SW	11	SW	9	NE	1	M	M	M	M	M	15	SW	14	25
26	NW	15	NW	17	W	21	W	8	S	8	W	11	SW	9	E	4	M	M	M	M	M	7	SW	7	26
27	NW	10	NW	12	M	22	W	16	S	7	SW	9	W	9	SW	3	M	M	M	13°	M	10	SW	9	27
28	NW	6	SW	6	NW	10	NW	5	SW	9	SW	7	W	7	E	3	M	M	S	9	M	10	SW	4	28
29	NW	16	M	M	NW	8	NW	8	S	6	W	8	W	5	SW	3	M	M	S	7	M	5	W	7	29
30	W	27	M	M	W	17	NW	8	M	9	SW	5	W	6	SW	6	M	M	W	10	M	2	W	14	30
31	W	11	M	M	NW	21	M	M	NW	6	M	M	N	6	SW	6	M	M	SW	5	M	M	NE	1°	31
MONTH MAX	W	27	W	21	W	22	W	21	W	13	M	12	SW	15	NE	7	SW	16	M	13	W	19	SW	19	MAX
AVE		14		10		13		09		07		08		07		04		07		05		07		06	AVE

YEARLY MAX -- W 27 MPH ON JAN 30

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1972

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	18	M	4	W	9	W	14	W	14	SW	3	SW	10	W	8	NE	2	SW	4	SW	6	W	14	1
2	M	27	M	7	M	11	W	11	W	7	S	5	SW	9	SW	6	SW	3	SW	10	W	3	SW	21	2
3	M	6	M	14	M	25	W	11	W	10	S	3	SW	9	S	4	SW	6	W	6	SW	3	SW	16	3
4	M	3	M	3	M	20	SW	18	SW	8	S	3	W	7	S	3	W	5	S	4	NE	1	SW	13	4
5	M	18	M	8	M	20	SW	13	SW	4	SW	3	W	6	SW	4	SW	12	W	2	NE	2	W	3	5
6	M	10	M	M	M	30	SW	16	S	5	S	6	W	8	SW	3	SW	17	VAR	1	W	5	W	3	6
7	M	4	M	M	M	24°	W	6	W	3	NE	6	W	6	W	5	SW	2	N	1	NE	2	SW	9	7
8	M	19	M	M	M	M	SW	12	SW	6	NE	2	W	4	S	5	SW	3	SW	2	SW	4	SW	6	8
9	M	22	M	8	M	M	SW	13	S	6	SW	2	SW	4	S	2	SW	5	SW	9	W	5	S	4	9
10	M	27	M	2	M	M	SW	12	S	6	SW	2	W	4	S	3	S	4	SW	6	NE	2	NE°	2	10
11	M	36	M	3	M	M	SW	14	W	6	W	6	W	5	S	4	S	3	SW	4	E	2	NE	2	11
12	M	38	M	11	M	M	SW	16	W	10	S	4	W	5	S	4	SW	5	W	1	E	3	SW	3	12
13	M	26	M	17	M	M	S	8	W	5	SW	6	M	9	S	5	SW	6	SW	4	N	1	W	4	13
14	M	18	M	15	M	M	NE	3	W	4	W	6	M	9	S	3	SW	7	S	4	NE	1	W	4	14
15	M	5	M	15	M	10	M	8	W	5	S	3	M	7	S	2	SW	10	SW°	5	W	5	SW	3	15
16	M	8	M	23	W	12	SW	6	S	4	S	3	M	7	S	3	M	10	SW°	13°	NE	2	NE	3	16
17	M	7	M	27	W	14	SW	10	SW	6	W	5	M	7	S	3	SW	12	SW	10	E	2	NE	2	17
18	M	17	M	14	SW	9	S	9	S	7	SW	11	S	9	E	4	S	4	S	2	NE	3	-	7	18
19	M	10	M	8	W	7	S	8	S	6	SW	16	S	5	W	2	S	5	S	3	NE	2	W	8	19
20	M	6	M	10	M	8	W	6	S	7	SW	15	S	5	M	4	W	4	S	4	S	3	W	13	20
21	M	16	M	7	SW	9	W	12	S	4	SW	13	S	10	SW	2	S	3	W	3	SW	3	SW	5	21
22	M	38	M	13	NE	6	W	17	SW	3	SW	4	S	8	W	4	SW	7	W	2	NE	2	SW	8	22
23	M	27	M	19	SW	9	W	6	SW	7	SW	8	S	4	S	5	SW	17	NE	1	NE	2	W	8	23
24	M	19	M	23	M	12	SW	7	S	6	M	5	S	4	SW	1	SW	11	E	4	W	9	SW	7	24
25	M	16	M	10	SW	16	SW	9	SW	8	SW	9	W	3	S	3	SW	16	W	3	W	12	SW	12	25
26	M	10	M	10	SW	10	W	8	W	3	SW	14	S	2	S	3	M	8	SW	2	W	29	SW	5	26
27	M	15	M	12	NE	1	W	6	W	4	W	13	W	4	S	4	SW	11	W	2	W	13	SW	4	27
28	M	21	M	21	M	4	W	9	W	6	W	6	W	5	S	2	SW	17	M	2	W	6	S	3	28
29	M	5	M	18	W	5	M	8	NE	4	NE	3	SW	4	W	4	W	12	SW	7	W	17	W	5	29
30	M	1	M	M	W	13	M	13	NE	3	W	6	W	6	SW	6	SW	4	S	3	W	21	W	10	30
31	M	1	M	M	W	13	M	M	SW	5	M	M	SW	6	S	3	M	M	NE	4	M	M	N	2	31
MONTH MAX	M	38	M	27	M	30	SW	18	W	14	SW	16	SW	10	W	8	SW	17	SW	13	W	29	SW	21	MAX
AVE		16		12		12		10		06		06		06		04		08		04		06		07	AVE

YEARLY MAX -- M 38 MPH ON JAN 12

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1973

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	NE	1	W	4	W	4	N	7	S	3	M	5	SW	11	M	5	S	9	SW	8	W	20	E	5	1
2	NE	1	NE	1	N	3	NE	8	NW	7	M	7	W	7	M	3	S	8	W	14	S	5	E	11	2
3	NE	2	NE	1	SW	3	NW	3	S	5	M	8	S	4	M	3	NW	8	SW	11	W	12	NW	7	3
4	N	2	W	4	S	4	W	3	SW	11	M	5	S	6	M	3	W	6	SW	6	W	11	W	11	4
5	N	2	W	3	W	5	M	5	S	5	M	7	SW	7	M	5	S	7	W	10	W	11	W	8	5
6	NE	1	NE	2	W	6	M	9	E	2	SW	6	SW	8	M	5	S	4	W	12	W	20	W	6	6
7	NE	2	SW	10	S	3	NE	9	W	7	W	7	S	5	M	5	S	9	W	8	W	22	W	6	7
8	SW	8	NE*	1	S	3	W	10	M	12	W	4	S	3	W	10	S	9	M	8	W	21	M	11	8
9	NE	1	M	M	S	3	M	12	M	19	SW	5	S	3	M	7	S	9	M	7	W	7	W	8	9
10	W	5	M	M	W	4	M	6	SW	20	SW	7	E	7	S	6	S	5	M	4	SW	8	W	7	10
11	NE	1	M	M	N	2	W	2	SW	10	W	7	S	3	S	4	S	6	M	10	W	5	SW	10	11
12	SW	14	M	M	S	5	W	5	M	6	S	4	S	3	S	6	NW	11	M	14	W	14	SW	18	12
13	SW	15	M	M	S	12	S	7	S	4	S	4	S	4	SW	4	N	9	M	8	W	12	SW	11	13
14	W	6	SW	4	W	10	S	5	S	4	S	4	SW	3	SW	12	W	10	M	5	W	17	W	13	14
15	NE	1	N	1	M	7	SW	5	SW	6	SW	6	W	5	W	8	W	13	M	6*	S	5	W	12	15
16	NE	2	N	2	W	5	SW	11	S	4	M	11	W	3	S	7	M	15	W*	11*	W	9	SW	7	16
17	M	5	N	1	SW	5	SW	6	SW	7	SW	13	W	2	S	8	NW	10	SW	6	W	13	SW	6	17
18	W	8	NE	3	SW	4	S	6	SW	11	W	18	E	3	W	10	W	15	W	8	S	6	NE	5	18
19	SW	5	W	7	S	2	W	17	SW	9	W*	6	S	4	S	7	NW	11	S	6	SE	7	M	1	19
20	N	3	S	2	N	3	SW	10	SW	10	W	8	S	6	S	7	SW	11	W	10	W	4	M	4	20
21	W	2	NE	2	S	6	W	3	S	5	S	3	S	5	S	5	W	16	W	8	W	5	M	3	21
22	SW	2	E	4	SW	8	W	8	S	4	S	4	S	5	NW	6	SW	8	S	5	W	5	M	7	22
23	S	1	N	2	NE	4	S	2	SW	12	W	5	SW	9	S	5	SW	13	SW	18	SW	6	M	2	23
24	E	1	NE	2	NW	2	NE	3	SW	13	SW	10	W	5	S	9	W	12	W	15	E	4	M	5	24
25	N	1	W	6	SW	3	M	7	SW*	9	SW	10	M	2	SW	9	NW	5	W	7	W	6	M	10	25
26	NE	4	SW	2	NE	3	W	5	M	11	W	8	M	3	S	7	W	4	W	9	W	4	M	8	26
27	W	2	N	2	S	3	SW	9	M	15	W	5	M	3	SW	9	SW	4	W	12	W	17	SW*	M	27
28	SW	6	N	2	S	2	SW	17	M	10	SW	6	M	2	S	8	W	8*	W	7	SE	7	M	M	28
29	SW	6	M	M	S	5	SW	13	M	9	W	7	M	3	S	6	SW	4	SE	6	W	9	M	M	29
30	SW	18	M	M	W	3	S*	4	M	3	S	3	M	2	S	5	SW	7	W	11	E	6	M	M	30
31	NE	2	M	M	W	9	M	M	M	3	M	M	M	3	SW	10	M	M	W	29	M	M	M	M	31
MONTH MAX	SW	18	SW	10	S	12	W	17	SW	20	W	18	SW	11	SW	12	W	16	W	29	W	22	SW	18	MAX
AVE		04		03		05		07		08		07		04		07		09		10		10		08	AVE

YEARLY MAX -- W 29 MPH ON OCT 31

VAR - VARIABLE DIRECTION
M = MISSING DATA
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1974

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	SW	14	SW	15	W	18	W	13	SW	8	SW	11	S	2	W	12	W	9	W	4	M	0	1
2	M	M	W	6	M	16	SW	9	W	18	M	M	W	12	S	2	W	6	SW	7	S	2	M	0	2
3	E	1	W	9	M	5	NW	5	W	9	M	M	W	8	S	2	W	4	SW	5	S	2	M	1	3
4	E	1	SW	17*	M	7	W	11	S	5	M	11	S	6	S	4	W	7	W	18	NW	2	S	1	4
5	SW	13	M	5	NE	5	W	10	N	5	M	10	S	6	S	4	W	12	SW	9	S	1	S	2	5
6	SW	23	SE	3	SW	10	M	16	M	9	M	7	S	3	S	5	W	9	W	4	S	1	NW	5	6
7	SW	18	W	5	SW	10	W	14	W	14	M	8	NE	2	SW	9	W	7	W	7		0	S	4	7
8	SW	4	W	8	SW	9	W	8	W	12	M	7	S	2	SW	6	S	6	SW	4	S	2		0	8
9	W	2	W	7	E	8	W	8	SW	14	M	11	M	3	S	8	W	7	S	5	S	4		0	9
10	SW	16	W	7	SW	6	NW	8	W	20	M	11	M	4	W	11	W	10	SW	4	NW	9		0	10
11	SW	21	W	8	W	10	W	16	SW	18	W	10	SW	4	W	15	W	9	S	2	NW	11	NW	7	11
12	E	7	SW	12	W	3	W	11	SW	17	W	8	S	5	S	7	SE	2	S	2	M	19	W	16	12
13	W	8	SW	3	SW	15	S	6	SW	15	W	10	S	2	S	5	W	2	S	3	NW	23	S	9	13
14	W	7	E	2	SW	19	SW	9	SW	16	NW	6	S	6	W	9	S	1	W	6	NW	14	NW	11	14
15	E	4	M	6	W	14	W	11	SW	23	S	7	S	3	W	10	S	3	W	4	W	11	NW	10	15
16	S	2	NE	3	W	13	W	5	SW	15	S	6	S	2	W	7	S	3	SW	2	W	4	NW	12	16
17	E	3	SE	4	W	20	NW	7	SW	9	S	6	S	2	W	8	S	6	NE	2		0	S	6	17
18	NE	2	W	6	W	15	S	6	S	8	W	5	S	2	S	7	S	2	S	2	SW	13	NW	6	18
19	SW	8	W	1	SW	12	S	8	S	10	S	5	S	3	SW	6	S	5	W	3	W	11	NW	16	19
20	W	6	NE	3	W	13	W	10	M	13	W	11	S	2	W	12	W	4	S	7	SW	4	NW	18	20
21	W	4	W	3	W	16	M	11	W	14	W	M	S	2	M	5	W	5	S	6	N	1	W	18	21
22	W	8	W	9	SW	19	M	6	W	8	S	M	S	1	S	5	S	3	S	4	N	2	NW	14	22
23	W	2	W	13	W	15	S	7	W	7	S	M	W	2	S	3	SW	3	S	4	SW*	7	S	4	23
24	SE	1	M	5	W	13	S	7	S	5	SW	M	E	2	S	3	S	5	W	1	M	4	S	2	24
25	SW	5	SW	3	W	19	S	4	W	9	S	S	W	3	S	2	SW	6	S	1	M	13		0	25
26	W	6	W	9	SW	9	M	10	W	10	W	8	S	4	E	5	W	8	SW	2	SW	12	S	1	26
27	W	5	SW	21	W	12	W	13	SW	11	S	4	S	2	S	4	W	8	S	2	SW	4	S	1	27
28	W	7	SW	15	W	21	S	5	M	15	W	7	S	2	W	6	W	11	S	2	M	2	S	2	28
29	W	14	M	M	SW	24	E	3	M	15	SW	6	S	1	W	11	SW	5	S	5	M	3	S	2	29
30	W	14	M	M	SW	17	M	4	W	10	S	6	S	1	W	12	W	8	NW	6	M	2		0	30
31	W	5	M	M	W	10	M	M	W	8	M	M	S	3	W	13	M	M	W	13	M	M		0	31
MONTH MAX	SW	23	SW	21	SW	24	M	18	SW	23	M	11	W	12	W	15	W	12	W	18	NW	23	NW	18	MAX
AVE		07		07		13		09		12		08		04		07		06		05		06		05	AVE

YEARLY MAX -- SW 24 MPH ON MAR 29

VAR - VARIABLE DIRECTION
M = MISSING DATA
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1975

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	VAR	2	S	8	W	9	W	7	SW	7	W	10	S	7	M	4		0	M	2	M	2	SW°	20	1
2	NW	6	VAR	1	VAR	8	NW	11	SW	5	NW	9	VAR	5	M	5	W	6	VAR°	2	SW°	4	SW	15	2
3	VAR	2	S	1	W	10	W	7	SW	10	W	11	VAR	4	M	M	SW	3	M	2	SW°	5	M	1	3
4	VAR	3		0	W	12	SW	11	S	7	W	8	VAR	3	M	M	VAR	5	SW	11	M	.	M	1	4
5	VAR	7	NW	6	W	15	VAR	5	S	6	W	5	VAR	2	M	M	W	6	W	7	M	1	W°	4	5
6	W	17	M	4	W	12	S	10	SW	10	W	9	VAR°	4	M	M	W	3	M	2	M	M°	W	10	6
7	W	16	M	11	W	9	M	11	SW	9	VAR	6	M	4	M	M	VAR	5	SW	11	M	16	W	7	7
8	VAR	2	M	22	W	4	M	10	SW	4	W	6	VAR	3	M	M	VAR	2	W°	14	M	3	W	12	8
9	NW	4	M	16	W	3	M	5	VAR	4	VAR	2	VAR	2	M	M	VAR°	2	VAR°	10	M	7	W	7	9
10	NW	7	M	13	VAR	3	M	3	SW	7	VAR	4	VAR	2	M	M	VAR°	2	M	M	M	11	W	10	10
11	NW	18	NW	11	VAR	2	M	4	SW	8	SW	9	VAR	4	M	M	S°	2	M	M	M	24	VAR°	4	11
12	VAR	6	VAR	4		0	M	4	W	8	SW	13	VAR	4	VAR	3	M	2	M	M	M	7	VAR°	7	12
13	VAR	9	W	12		0	M	7	W	8	SW	16	VAR	5	VAR	2	M	1	M	M	M	1	M	2	13
14	W	13	VAR	1		0	M	8	W	5	SW	17	S	5	SW	4	M	2	W	13	M	0	VAR	3	14
15	W	11		0		0	M	8	VAR	5	SW	16	VAR	4	SW	3	M	2	W°	4	M	2	SW	19	15
16	W	13	VAR	2	S	3	M	11	S	6	SW	15	VAR	4	VAR	4	SW°	9	W	12	M	2	SW	24	16
17	NW	7	VAR	4	VAR	5	M	M	VAR	2	S	8	SW	8	W	5	SW	19	W°	7	M	7	W	14	17
18	NW	13	NW	5	W	9	M	M	VAR	5	S	7	SW	6	S	6	W	8	W°	1	M	5	M	0	18
19	NW	9	VAR	4	W	12	M	M	W	9	S	5	VAR	4	W	5	W	10	W°	3	VAR°	5	M	1	19
20	W	18	W	14	W	15	M	M	S	10	S	5	VAR	3	VAR	1	W°	5	W°	8	M	2	M	0	20
21	S	6	E	4	W	12	M	M	S	9	VAR	5	VAR	3	VAR	1	VAR°	2	S°	8	M	1	M	1	21
22	VAR	1	W	5	W	13	SW	11	VAR	3	VAR	2	VAR	5	VAR	4	M	2	SW°	9	M	0	M	1	22
23	NW	8	W	2	W	20	SW	10	W	7	VAR	4	VAR	3	SW	11	VAR°	2	S°	4	W	12	M	1	23
24	NW	28	W	8	W	18	VAR	4	W	8	S	7	VAR	3	SW	18	VAR°	2	W°	7	W	17	W°	3	24
25	NW	31	W	5	S	5	S	12	SE	6	S	12	VAR	3	W	7	W°	5	E°	2	W	8	W°	4	25
26	W	22	W	9	VAR	5	S	8	VAR	5	VAR	8	NE	5	W	7	W	12	SW	14	W°	.	W	4	26
27	VAR	8	W	15	NW	5	W	13	VAR	3	SW	9	VAR	5	SW	6	W	12	SW°	8	VAR°	7	W	20	27
28	W	11	W	20		0	W	14	S	7	S	8	VAR	5	W	8	W	8	SW°	7	VAR°	7	M	2	28
29	W	6	M	M	W	4	SW	7	S	7	S	8	VAR	3	SW	7	SW	11	S°	4	SW°	4	M	1	29
30	VAR	3	M	M	W	6	SW	7	VAR	4	S	7	M	3	VAR	3	VAR°	3	SW°	8	SW	27	M	1	30
31	W	8	M	M	W	9	M	M	W	7	M	M	M	4	W	4	M	M	N°	3	M	.	NE°	8	31
MONTH MAX	NW	31	M	22	W	20	W	14	SW	10	SW	17	SW	8	SW	16	SW	19	W	14	SW	27	S	24	MAX
AVE		10		07		07		08		06		08		04		05		05		06		07		07	AVE

YEARLY MAX -- NW 31 MPH ON JAN 25

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA

Maximum Hourly Winds

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1968

MAXIMUM HOURLY WINDS - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	360	41	180	9	270	12	320	9	320	9	320	10	320	11	320	11	320	19	320	4	320	24	1
2	M	M	360	21	320	13	270	14	320	11	220	9	220	12	090	8	270	21	320	16	320	12	320	26	2
3	M	M	360	15	320	M	320	20	360	12	320	15	180	10	320	8	220	15	320	13	270	8	320	34	3
4	360	10	360	8	040	6	320	8	220	11	270	13	220	13	360	13	270	16	320	10	320	24	M	M	4
5	320	26	360	6	040	6	320	12	320	12	320	11	220	8	220	12	320	10	320	13	360	8	M	M	5
6	320	26	360	9	090	5	320	24	320	15	320	12	360	9	090	13	320	16	320	15	320	12	M	M	6
7	360	7	090	7	320	17	320	24	320	29	320	14	360	8	180	11	320	20	320	14	360	8	M	M	7
8	320	24	360	11	320	24	320	14	320	20	320	12	320	9	320	7	320	10	M	M	320	18	M	M	8
9	320	14	090	6	320	14	320	13	270	14	320	8	320	8	220	6	320	9	270*	8	320	38	M	M	9
10	320	9	320	9	220	15	320	11	090	10	320	13	320	11	360	4	220	8	320	12	320	20	M	M	10
11	320	21	360	16	320	14	090	9	220	12	320	14	320	11	320	16	320	8	220	8	320	16	M	M	11
12	360	9	320	14	360	12	320	17	270	13	320	13	270	16	360	10	320	15	320	15	320	30	M	M	12
13	360	12	090	6	320	34	320	29	320	35	320	33	320	10	320	8	270	16	320	17	320	10	M	M	13
14	360	9	320	10	320	24	320	40	320	21	320	16	320	12	320	19	270	16	320	27	090	4	M	M	14
15	320	5	320	22	320	16	320	24	320	23	320	18	320	10	320	22	270	24	320	15	320	32	M	M	15
16	320	8	320	29	320	20	320	26	320	12	320	13	320	12	320	10	270	17	320	19	320	36	M	M	16
17	360	13	320	20	320	21	180	16	320	16	320	12	320	9	320	15	320	15	320	15	320	22	M	M	17
18	180	6	320	22	320	22	220	15	320	17	320	13	320	M	320	30	270	16	320	32	320	22	M	M	18
19	270	4	320	23	090	10	320	22	320	14	320	10	220	11	320	19	270	10	270	12	320	12	M	M	19
20	180	10	320	18	360	12	360	11	320	14	320	19	320	25	320	9	270	15	320	32	320	10	M	M	20
21	040	3	320	17	320	23	320	12	320	15	320	9	180	10	220	9	270	14	320	20	320	6	M	M	21
22	090	13	320	21	320	17	090	10	320	15	320	11	320	10	320	8	220	11	320	25	320	16	M	M	22
23	360	7	320	27	090	8	320	16	090	11	320	11	270	9	320	30	320	11	320	35	320	21	M	M	23
24	360	5	320	30	320	18	320	14	270	9	320	17	090	8	320	10	320	9	320	17	320	20	M	M	24
25	090	6	320	28	320	16	320	16	320	15	320	13	090	9	320	10	270	9	320	8	320	19	M	M	25
26	180	7	360	10	320	26	320	15	320	16	320	14	140	11	220	10	320	9	320	15	320	7	M	M	26
27	320	16	270	9	320	28	140	14	320	20	320	12	140	12	320	12	320	14	320	29	180	6	M	M	27
28	320	19	320	13	320	12	320	14	320	11	320	20	180	15	270	12	140	10	320	16	140	8	M	M	28
29	360	15	320	9	270	13	360	7	320	14	320	27	270	10	220	10	270	10	360	6	320	8	M	M	29
30	360	19	M	M	270	14	360	13	320	24	320	17	270	12	320	7	270	21	320	12	VAR	6	M	M	30
31	360	21	M	M	320	10	M	M	270	10	M	M	270	11	270	8	M	M	320	16	M	M	M	M	31
MONTH MAX	320	26	360	41	320	34	320	40	320	35	320	33	320	25	320	30	270	24	320	35	320	38	320	34	MAX
AVE		12		16		16		16		15		14		11		12		14		17		15		28	AVE

YEARLY MAX -- 41 MPH ON FEB 1

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1969

MAXIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	M	M	M	M	220	14	220	10	M	M	M	M	M	M	220	13	040	08	270	20	270	08	090	06	1
2	M	M	M	M	090	10	220	08	M	M	M	M	M	M	220	15	270	10	270	25	220	11	090	04	2
3	M	M	M	M	180	08	220	16	M	M	M	M	M	M	270	10	270	11	270	08	220	07	VAR	04	3
4	M	M	M	M	140	12	270	11	M	M	M	M	M	M	090	10	270	22	090	06	270	09	270	13	4
5	M	M	M	M	220	11	180	08	M	M	M	M	M	M	270	10	270	22	270	10	090	04	090	04	5
6	M	M	270	19	M	M	220	22	M	M	M	M	M	M	270	25	220	12	270	11	220	08	270	11	6
7	M	M	270	17	M	M	220	38	M	M	M	M	M	M	270	13	040	14	270	09	270	21	320	11	7
8	M	M	140	08	M	M	270	16	M	M	M	M	M	M	220	15	360	10	270	31	270	15	320	17	8
9	M	M	270	14	M	M	270	13	M	M	M	M	M	M	220	12	220	05	270	30	270	16	270	08	9
10	M	M	270	24	M	M	220	09	M	M	040	13	320	08	220	11	320	10	090	14	270	30	270	28	10
11	M	M	270	15	M	M	090	12	M	M	270*	12	040	09	320	16	320	11	090	15	270	28	270	24	11
12	M	M	220	07	M	M	220	07	M	M	220	18	140	10	270	15	270	12	090	10	220	33	320	16	12
13	M	M	220	12	220	10	220	10	M	M	220	11	140	15	360	06	270	18	270	19	220	27	320	20	13
14	M	M	270	14	140	12	140	14	M	M	220	11	270	15	220	12	180	05	270	20	220	20	360	05	14
15	270	30	270	16	270	09	140	12	M	M	040	06	270	12	220	15	040	10	220	15	270	16	180	04	15
16	320	22	320	10	220	10	180	05	M	M	180	11	360	40	270	15	040	06	270	12	270	25	090	05	16
17	320	28	320	10	270	20	270	09	M	M	040	03	040	11	090	10	270	09	270	17	220	15	320	18	17
18	320	16	180	13	270	26	220	08	M	M	220	07	040	11	220	13	360	06	270	12	270*	20	VAR	04	18
19	090	06	220	14	270	42	M	M	M	M	320	11	M	M	140	05	220	10	270	20	M	M	320	14	19
20	320	32	270	10	270	09	M	M	M	M	220	20	M	M	090	08	320	10	090	03	270	10	320	35	20
21	320	08	320	10	270	20	M	M	M	M	220	16	M	M	090	10	270	10	360	09	270	05	270	26	21
22	220*	20	270	12	320	18	M	M	M	M	220	14	M	M	320	05	220	06	090	06	220	10	270	35	22
23	270	22	220	14	270	22	M	M	M	M	270	11	270*	08	270	13	270	11	270	10	VAR	01	270	39	23
24	270	22	220	25	220	14	220	16	M	M	270	20	270	07	270	06	270	17	220	06	270	11	320	30	24
25	270	20	220	30	220	16	270	32	M	M	M	M	220	10	040	08	270	18	040	04	270	12	270	21	25
26	220	22	270	25	320	15	320	18	M	M	M	M	270	14	M	M	270	09	320	05	320	15	270	23	26
27	270	28	320	21	270	30	320	21	M	M	M	M	360	09	M	M	220	10	220	10	270	02	090	04	27
28	220	21	220	12	220	28	320	13	M	M	M	M	220	11	M	M	270	13	270	15	220	03	220	02	28
29	M	M	M	M	270	22	270	20	M	M	M	M	320	15	320	06	270	09	220	15	090	02	090	02	29
30	M	M	M	M	270	18	M	M	M	M	M	M	040	11	220	09	270	26	270	09	090	05	270	11	30
31	M	M	M	M	220	26	M	M	M	M	M	M	270	10	180	08	M	M	270	10	M	M	320	09	31
MONTH MAX	320	32	220	30	270	42	220	38			220	20	360	40	270	25	270	26	270	31	220	33	270	39	MAX
AVE		21		15		18		15				12		13		11		12		13		13		15	AVE

YEARLY MAX -- 42 MPH ON MAR 19

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1970

MAXIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	270	10	M	M	180	11	320	25	270	10	320	08	270*	12	220	12	270	16	090	08	270	14	270	27	1
2	270	15	M	M	270	23	320	29	320	12	090	10	270	10	220	11	220	20	180	09	320	10	270	36	2
3	320	25	M	M	270	21	270	11	180	11	140	13	180	15	180	16	270	22	270	10	320	06	270	46	3
4	270*	23	M	M	270	13	270	18	270	13	090	14	220	16	270	12	270	14	320	06	040	03	320	15	4
5	M	M	270	29	M	M	270	22	270	09	180	10	220	09	180	11	220	09	270	16	320	18	320	12	5
6	M	M	320	12	M	M	220	12	220	12	220	15	320	08	220	08	270	33	220	12	270	16	270	07	6
7	M	M	270	11	M	M	270	26	270	20	220	12	140	06	220	06	270	35	220	15	270	12	270	09	7
8	270	11	270	12	M	M	270	24	270	27	270	10	220	11	270*	13	270	19	270	12	320	21	270	33	8
9	320	15	270	08	M	M	270	09	270	27	270	12	220	11	M	M	270	29	270	15	320	12	270	16	9
10	270	19	320	13	M	M	270	32	270	22	270	20	270	11	M	M	270	22	270	25	270	30	320	09	10
11	270	16	270	12	M	M	320	25	270	22	320	13	180	14	M	M	270	37	270	12	270	16	270	33	11
12	270	15	270	20	320	16	320	20	270	25	270	18	270	12	320*	12	270	23	270	19	270	26	270	20	12
13	320	18	270	27	270	28	180	13	270	22	220	12	270	11	270	15	270	30	320	09	090	09	220	11	13
14	220	12	270	09	270	23	180	20	320	17	270	16	270	16	270	13	270	20	220	06	320	09	270	10	14
15	320	12	270	09	270	07	270	26	270	17	270	17	220	15	220	10	270	11	140	05	140	05	320	20	15
16	270	15	270	30	270	12	180	17	270	14	270	22	270	11	270	10	270	15	040	05	270	17	270	30	16
17	270	25	270	35	270	15	180	12	270	20	270	18	270	14	270	14	270	09	140	10	320	15	270	17	17
18	270	25	320	25	270	08	320	23	270	17	270	16	180	09	320	10	140	07	270	05	270	27	270	27	18
19	270	40	320	08	320	10	320	26	270	16	270	12	220	15	090	06	270	20	270	15	320	22	270	25	19
20	270	31	220	08	270	09	270	27	270	20	180	10	270	16	220	12	270	35	270	11	270	29	270	06	20
21	270	31	220	09	270	16	270	15	220	16	180	10	320	12	040	06	090	05	270	17	270	44	270	16	21
22	270	33	180	14	270	20	270	27	180	16	270	14	270	12	M	M	270	14	320	06	270	35	270	40	22
23	270	25	220	10	270	26	320	13	270	14	270	11	220	15	M	M	270	25	320	09	270	31	320	20	23
24	270	40	090	04	270	39	270	17	270	15	270	15	320	10	M	M	270	22	270	19	270	39	270	32	24
25	270	30	270	10	320	20	270	22	M	M	270	19	270	11	M	M	270	11	270	20	270	32	270	17	25
26	270	30	270	10	270	11	270	25	M	M	270*	15	320	10	220*	12	270	06	270	10	270	21	090	04	26
27	270	29	270	10	270	11	270	15	220*	10	M	M	270	17	220	20	040	04	320	14	270	25	270	30	27
28	270	24	270	08	320	11	270	15	270	19	M	M	270	16	270	17	220	08	270	26	270	31	320	20	28
29	270	22	M	M	140	09	320	10	270	14	M	M	270	11	270	09	180	09	270	30	270	22	270	22	29
30	090	05	M	M	140	17	320	08	270	20	M	M	270	16	220	19	320	07	270	33	270	50	320	35	30
31	270	10	M	M	270	10	M	M	270	11	M	M	270	09	090	10	M	M	270	20	M	M	270	36	31
MONTH MAX	270	40	270	35	270	39	270	32	270	27	270	22	270	17	220	20	270	37	270	33	270	50	270	46	MAX
AVE		22		14		16		19		17		14		12		12		18		14		22		22	AVE

YEARLY MAX -- 50 MPH ON NOV 30

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1971

MAXIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	270	28	270	10	140	12	270	25	270	13	270	14	220	13	180	10	220	09	M	M	270	32	M	M	1
2	220	19	320	07	320	15	320	24	320	13	270	13	220	16	220	10	220	15	M	M	270	32	270	06	2
3	180	17	270	20	270	25	320	16	270	12	180	12	270	17	090	10	220	15	M	M	270	15	270	06	3
4	320	17	270	37	270	20	270	21	270	12	270	20	270	18	040	09	220	26	M	M	270	33	220	05	4
5	320	16	270	35	320	17	270	20	320	22	270	17	220	16	040	10	220	20	M	M	270	30	220	21	5
6	320	06	320	25	270	26	220	09	180	13	270	20	220	19	040	10	220	09	M	M	270	16	220	10	6
7	040	02	320	23	320	29	270	15	180	10	270	13	270	12	M	M	220	14	M	M	220	04	180	13	7
8	270	32	270	20	270	13	270	25	270	12	220	14	220	20	M	M	220	11	270	08	270	15	220	14	8
9	270	40	320	13	270	20	220	15	270	15	M	M	180	20	M	M	270	10	220	05	270	15	270	15	9
10	270	43	270	37	270	27	270	35	270	10	M	M	220	15	M	M	220	09	270	11	270	10	270	25	10
11	270	29	320	35	320	16	270	32	090	11	M	M	220	22	140	14	220	13	220	13	270	13	270	13	11
12	320	30	320	13	320	29	270	30	090	07	M	M	270	27	180	11	270	07	220	13	220	09	270	20	12
13	270	27	320	21	270	23	220	12	220	10	M	M	270	14	040	10	270	15	220	20	270	22	040	02	13
14	270	45	320	20	270	40	220	16	270	12	M	M	220	16	140	12	220	20	220	20	140	07	220	04	14
15	270	41	270	33	270	45	320	11	270	15	M	M	220	13	270	10	270	16	220	16	180	13	270	14	15
16	270	34	270	30	320	21	270	13	270	26	M	M	140	12	220	10	220	22	180	12	140	12	270	12	16
17	270	32	270	19	270	21	220	13	270	08	M	M	180	13	140	11	140	11	220	14	040	04	M	M	17
18	270	25	270	18	320	20	140	12	320	10	M	M	040	10	220	09	220	09	360	15	270	09	M	M	18
19	320	15	270	16	320	15	140	15	270	20	M	M	180	08	140	14	220	11	140	04	270	06	M	M	19
20	270	40	140	12	320	26	320	27	270	17	M	M	220	10	360	04	220	10	360	03	270*	04	M	M	20
21	270	38	320	05	270	25	320	17	270	11	M	M	220	10	040	07	220	10	040	04	M	M	M	M	21
22	270	43	090	05	320	30	140	06	270	18	M	M	180	08	090	09	M	M	270*	06	M	M	M	M	22
23	320	20	320	12	270	31	220	07	270	13	220	14	220	08	220	09	M	M	M	M	M	M	220	28	23
24	270	39	320	09	320	25	270	18	270	17	270	18	270	12	090	09	M	M	M	M	M	M	270	20	24
25	270	47	270	37	320	22	140	13	270	15	270	16	270	19	360	04	M	M	M	M	M	M	220	26	25
26	320	23	270	31	270	36	270	19	180	13	270	14	270	17	220	15	M	M	M	M	M	M	220	18	26
27	320	20	320	21	270	31	270	26	180	13	270	17	270	16	180	14	M	M	M	M	M	M	220	20	27
28	320	21	270	18	270	21	320	10	180	12	220	13	270	14	220	10	M	M	220	11	M	M	220	10	28
29	270	35	M	M	320	13	320	14	270	15	270	12	270	14	220	10	M	M	140	15	M	M	270	21	29
30	270	45	M	M	270	33	320	13	270	20	220	15	270	13	220	12	M	M	270	27	M	M	270	25	30
31	270	20	M	M	270	27	M	M	320	13	M	M	220	12	220	15	M	M	220	15	M	M	220*	05	31
MONTH MAX	270	47	270	37	270	45	270	35	270	26	270	20	270	27	220	15	220	26	270	27	270	33	220	28	MAX
AVE		29		21		24		18		14		15		15		10		13		12		15		15	AVE

YEARLY MAX -- 47 MPH ON JAN 25

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1972

MAXIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	M	M	M	M	270	16	240	24	260	24	230	7	180	19	240	13	210	10	230	10	240	19	240	25	1
2	M	M	M	M	M	M	240	17	270	13	180	12	240	16	250	16	270	10	240	17	280	6	240	31	2
3	M	M	M	M	M	M	250	18	270	17	210	9	220	20	180	9	220	19	270	14	270	5	240	23	3
4	M	M	M	M	M	M	240	24	240	15	100	9	260	15	240	9	230	13	220	10	100	2	230	26	4
5	M	M	M	M	M	M	230	24	210	10	210	11	270	12	230	14	250	21	260	5	220	10	280	10	5
6	M	M	M	M	M	M	240	26	180	11	180	15	250	25	270	10	230	36	030	4	250	10	250	9	6
7	M	M	M	M	M	M	270	14	220	9	230	10	230	14	260	11	240	7	020	3	030	6	230	20	7
8	M	M	M	M	M	M	240	22	240	13	030	7	180	10	080	12	220	9	180	5	240	11	230	25	8
9	M	M	M	M	M	M	210	19	180	11	250	4	180	11	330	7	200	15	230	20	270	9	240	15	9
10	M	M	M	M	M	M	240	25	180	12	230	7	270	12	180	9	190	11	240	16	180	5	030*	4	10
11	M	M	M	M	M	M	240	24	240	12	240	11	270	12	040	14	230	6	240	14	200	5	180	9	11
12	M	M	M	M	M	M	240	30	260	16	230	16	270	10	180	9	240	11	250	4	100	7	220	13	12
13	M	M	M	M	M	M	200	16	260	14	240	21	M	M	040	11	240	15	240	11	260	4	230	13	13
14	M	M	M	M	M	M	100	5	270	8	270	13	M	M	220	9	230	13	230	M	060	3	240	12	14
15	M	M	M	M	240	17	250	18	250	10	210	12	M	M	180	6	240	17	230*	25	260	14	240	10	15
16	M	M	M	M	240	22	240	14	180	9	180	13	M	M	230	10	270	16	230*	26	270	9	210	10	16
17	M	M	M	M	240	20	230	17	250	14	220	14	M	M	180	10	230	22	240	20	080	3	210	10	17
18	M	M	M	M	230	19	180	14	180	12	230	25	230	14	080	15	200	7	180	7	260	9	260	16	18
19	M	M	M	M	230	16	180	22	180	13	240	22	250	11	270	5	250	11	220	6	180	9	250	18	19
20	M	M	M	M	240	15	270	15	220	15	230	25	180	12	280	10	250	12	230	11	090	8	260	16	20
21	M	M	M	M	270	17	250	20	040	15	250	23	240	15	280	6	210	9	260	6	240	9	230	13	21
22	M	M	M	M	240	18	240	27	230	8	230	14	180	20	260	13	230	12	260	6	260	7	240	20	22
23	M	M	M	M	230	18	270	13	240	16	210	16	160	10	240	12	240	28	180	4	020	3	250	20	23
24	M	M	M	M	260	18	240	11	210	10	240	15	290	10	220	2	230	21	180	12	260	20	240	24	24
25	M	M	M	M	240	26	280	14	230	11	230	16	240	5	060	8	220	27	270	8	240	20	240	24	25
26	M	M	M	M	180	23	280	12	180	8	240	25	180	6	120	9	250	17	240	5	240	44	230	15	26
27	M	M	M	M	030	3	260	9	260	10	260	21	250	10	170	10	240	29	210	4	260	30	230	9	27
28	M	M	M	M	260	10	240	14	270	19	280	11	270	10	180	10	230	29	230	5	250	15	200	10	28
29	M	M	M	M	240	10	210	15	100	9	060	10	270	9	240	10	270	23	230	14	250	35	250	12	29
30	M	M	M	M	240	16	240	25	220	9	230	15	260	15	280	11	270	9	120	9	250	29	230	20	30
31	M	M	M	M	270	20	M	M	260	9	M	M	210	14	280	5	M	M	060	13	M	M	240	9	31
MONTH MAX					240	26	240	30	260	24	230	25	250	25	250	16	230	36	230	26	240	44	240	31	MAX
AVE						17		18		12		14		13		10		16		10		12		16	AVE

YEARLY MAX -- 44 MPH ON NOV 26

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1973

MAXIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	030	2	250	13	260	9	230	17	180	6	M	M	240	22	M	M	260	15	230	13	250	36	220	12	1
2	050	2	030	1	230	9	040	13	300	11	M	M	280	13	M	M	280	19	260	23	220	27	230	25	2
3	190	7	020	3	240	7	280	8	280	13	M	M	250	9	M	M	300	17	260	21	250	25	120	14	3
4	230	10	240	10	180	12	230	8	230	18	M	M	280	13	M	M	180	13	230	9	260	31	290	16	4
5	230	7	260	13	230	14	250	12	160	13	M	M	280	13	M	M	180	16	250	18	250	22	280	13	5
6	190	4	230	10	230	13	260	20	170	3	280	9	230	14	M	M	170	8	250	20	270	36	260	10	6
7	080	5	230	19	180	10	100	16	300	12	270	11	220	17	M	M	180	14	250	18	270	29	260	16	7
8	240	17	010*	3	100	7	260	24	260	29	250	8	180	15	260	14	270	14	M	M	260	37	260	26	8
9	030	2	M	M	180	11	250	20	220	30	240	9	100	8	270	13	180	14	M	M	210	19	280	13	9
10	250	10	M	M	270	11	270	15	200	29	260	14	120	11	180	23	170	9	M	M	220	15	260	17	10
11	270	4	M	M	230	7	270	7	210	17	230	14	180	9	210	9	300	16	M	M	260	9	230	29	11
12	240	35	M	M	180	11	270	9	230	15	180	12	180	10	270	15	330	20	M	M	250	30	240	35	12
13	230	35	M	M	270	25	210	16	180	9	150	16	180	11	240	11	310	15	M	M	250	25	230	26	13
14	260	10	270	11	250	22	210	18	120	10	250	15	210	10	230	18	280	15	M	M	270	25	250	20	14
15	210	4	010	2	260	19	240	13	210	13	240	15	210	15	270	13	300	20	M	M	260	16	260	20	15
16	200	5	020	4	250	13	230	20	250	8	260	20	240	12	210	16	270	30	310*	16	270	24	230	15	16
17	240	14	060	2	240	15	250	14	220	16	250	23	230	7	240	15	330	23	220	11	260	28	180	14	17
18	250	15	240	12	230	14	180	10	210	19	250	30	130	9	260	16	300	21	320	14	230	15	060	11	18
19	230	15	250	15	250	5	250	25	220	16	240*	10	210	12	170	17	300	20	180	14	100	14	M	M	19
20	240	8	250	6	180	7	240	19	210	24	270	13	260	17	230	14	260	22	260	17	150	10	M	M	20
21	260	7	060	5	180	15	280	8	190	20	270	10	240	15	230	12	250	40	250	16	240	12	M	M	21
22	250	7	110	9	230	15	230	17	190	11	120	9	230	15	300	13	240	18	220	9	230	14	M	M	22
23	200	3	260	9	040	10	180	10	210	15	230	10	230	20	240	10	220	22	260	29	240	13	M	M	23
24	050	2	250	5	300	5	240	5	220	18	250	16	230	20	180	15	280	18	270	30	300	10	M	M	24
25	020	2	250	16	260	8	250	17	200*	16	240	16	M	M	240	16	180	11	270	18	260	12	M	M	25
26	050	10	240	5	020	7	270	11	M	M	280	13	M	M	230	15	280	9	290	18	290	9	M	M	26
27	280	3	010	5	120	9	230	20	M	M	270	10	M	M	240	13	280	9	270	17	270	35	M	M	27
28	230	24	230	6	180	6	230	30	M	M	280	21	M	M	330	15	280*	13	270	13	270	26	M	M	28
29	220	25	M	M	180	10	210	28	M	M	290	13	M	M	230	10	230	10	110	13	250	22	M	M	29
30	230	35	M	M	230	9	180*	10	M	M	180	6	M	M	250	10	270	15	270	23	250	16	M	M	30
31	220	6	M	M	230	20	M	M	M	M	M	M	M	M	270	19	M	M	250	40	M	M	M	M	31
MONTH MAX	240	35	230	19	270	25	230	30	220	30	250	30	240	22	180	23	250	40	250	40	260	37	240	35	MAX
AVE		11		08		11		15		16		14		13		14		17		18		21		18	AVE

YEARLY MAX -- 40 MPH ON SEP 21

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1974

MAXIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	M	M	230	21	230	35	250	27	260	24	230	12	220	20	170	5	260	19	260	14	270	9	M	M	1
2	M	M	280	11	M	M	230	25	270	29	M	M	260	22	180	6	250	10	280	10	170	9	M	M	2
3	110	3	240	23	M	M	300	10	230	21	M	M	290	13	180	4	250	11	250	16	170	7	M	M	3
4	080	3	240*	28	M	M	280	17	280	14	M	M	210	10	230	14	280	15	250	31	320	8	170	5	4
5	230	29	230	17	230	15	280	19	180	14	M	M	200	17	150	10	230	20	230	20	180	4	330	7	5
6	220	29	140	9	230	21	280	26	230	14	M	M	120	11	280	10	280	16	270	10	300	6	310	9	6
7	220	35	240	9	190	17	280	21	260	17	M	M	120	11	210	14	280	13	280	10	170	2	180	9	7
8	230	11	250	13	200	19	280	21	250	18	M	M	330	9	240	13	270	14	180	10	190	6	200	1	8
9	260	9	260	25	070	12	250	15	230	26	M	M	M	M	270	25	240	16	210	13	300	9		0	9
10	230	32	250	18	230	17	310	13	230	34	M	M	M	M	250	19	250	16	230	12	310	15	170	2	10
11	230	40	250	20	240	25	300	20	230	25	280	14	220	9	250	23	270	19	180	7	310	15	300	21	11
12	230	26	330	25	260	11	280	25	220	27	280	14	170	12	220	15	240	11	100	7	280	30	290	25	12
13	250	22	230	6	250	30	300	10	220	30	270	18	140	9	210	11	280	8	180	10	280	35	280	18	13
14	250	26	230	4	250	26	360	14	230	26	290	13	180	12	250	15	270	10	250	13	280	21	300	17	14
15	230	11	240	20	260	22	270	14	230	33	180	12	110	7	260	15	180	8	260	9	280	19	320	16	15
16	210	7	240	19	250	18	250	13	230	20	230	19	170	10	280	11	170	10	220	7	270	12	280	22	16
17	270	10	240	11	230	32	320	12	210	15	210	15	180	9	250	13	140	9	250	6	050	2	180	18	17
18	240	9	290	13	240	25	230	11	220	12	280	12	180	8	270	13	190	5	190	4	230	30	290	13	18
19	250	20	240	5	240	26	260	17	180	15	280	10	170	10	210	11	210	9	250	9	250	20	320	30	19
20	240	24	250	8	240	20	290	16	260	23	230	14	220	7	250	21	280	10	230	15	230	9	310	28	20
21	240	15	250	15	240	21	M	M	250	23	M	M	230	7	250	13	290	13	180	11	050	5	270	38	21
22	250	17	240	25	240	31	M	M	250	14	M	M	110	9	200	8	290	8	090	8	040	5	280	34	22
23	250	5	260	25	260	25	210	11	260	15	M	M	280	6	220	8	230	9	200	11	240*	11	180	16	23
24	120	2	240	9	240	25	230	16	320	10	M	M	180	6	180	7	150	11	270	4	M	M	350	5	24
25	230	20	240	7	240	30	230	7	280	15	080	11	280	9	100	7	290	10	190	6	M	M	170	4	25
26	250	16	250	24	250	15	230	17	250	12	280	13	180	15	100	14	280	13	260	8	230	18	170	4	26
27	280	11	220	36	250	19	270	20	240	15	240	8	180	12	170	11	260	13	110	7	230	13	180	12	27
28	280	13	220	26	230	40	270	11	250	23	300	12	160	10	180	15	270	18	180	7	M	M	180	12	28
29	250	30	M	M	230	32	220	7	240	22	250	11	170	6	260	16	260	9	170	11	M	M	170	9	29
30	280	23	M	M	230	31	220	9	250	25	280	12	280	8	290	17	280	15	290	10	M	M	150	2	30
31	250	14	M	M	260	21	M	M	280	14	M	M	170	8	270	20	M	M	270	23	M	M	240	7	31
MONTH MAX	230	40	220	36	230	40	250	27	230	34	230	19	260	22	270	25	230	20	250	31	280	35	270	38	MAX
AVE		18		17		24		16		20		13		10		13		12		11		13		14	AVE

YEARLY MAX -- 40 MPH ON JAN 11

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1975

MAXIMUM HOURLY WINDS - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	240	8	290	19	280	15	240	13	230	13	260	14	180	10	M	M		0	M	M	M	M	240*	35	1
2	290	11	170	4	250	23	270	18	250	11	300	15	060	12	M	M	240	14	VAR*	4	220*	10	240	37	2
3	VAR	8	180	4	290	14	260	17	260	14	260	18	110	10	M	M	250	10	M	M	240*	12	M	M	3
4	310	13	180	2	260	23	250	18	190	10	260	17	190	10	M	M	140	10	240	18	M	M	M	M	4
5	320	15	320	18	250	30	230	14	190	12	250	11	080	8	M	M	270	10	280	12	M	M	VAR*	9	5
6	290	38G	M	M	260	30	230	20	220	15	200	17	180*	9	M	M	270	10	M	M	M	M	250	23	6
7	270	27	M	M	260	20	M	M	220	17	270	13	M	M	M	M	180	9	220	16	M	M	240	16	7
8	280	12	M	M	250	13	M	M	230	11	270	10	090	10	M	M	120	6	240*	35	M	M	250	18	8
9	280	10	M	M	290	10	M	M	180	8	230	7	210	9	M	M	180*	10	VAR*	4	M	M	260	12	9
10	300	15	M	M	290	10	M	M	260	11	060	9	VAR	5	M	M	240*	5	M	M	M	M	240	30	10
11	320	24	290	24	300	6	M	M	230	14	230	15	240	12	M	M	180*	6	M	M	M	M	250*	12	11
12	300	13	270	19	VAR	2	M	M	180	17	210	20	180	10	180	13	M	M	M	M	M	M	240*	17	12
13	300	20	270	34	310	10	M	M	290	13	210	28	220	8	250	12	M	M	M	M	M	M	M	M	13
14	280	31	090	7		0	M	M	280	10	240	25	160	10	220	13	M	M	240	26	M	M	220	8	14
15	270	23	230	3		0	M	M	180	10	220	22	190	11	220	10	M	M	270*	13	M	M	230	34	15
16	280	24	290	8	280	12	M	M	210	10	210	25	190	15	210	11	230*	22	270	22	M	M	230	31G	16
17	290	14	290	8	270	12	M	M	180	7	190	14	230	16	210	10	240	25	260*	15	M	M	250	33G	17
18	290	35G	290	10	310	16	M	M	210	13	180	10	200	10	230	11	230	13	280*	5	M	M	M	M	18
19	310	15	290	13	270	25	M	M	250	14	200	13	260	9	250	10	250	15	290*	9	100*	14	M	M	19
20	270	38	280	21	260	29	M	M	180	14	180	14	200	13	VAR	5	230*	15	280*	12	M	M	M	M	20
21	280	18	290	10	260	24	M	M	180	14	220	14	210	11	180	5	VAR*	4	220*	13	M	M	M	M	21
22	280	11	290	13	230	30	230	19	290	8	230	9	220	14	260	12	M	M	240*	19	M	M	M	M	22
23	280	19	260	6	290	28G	240	14	260	12	210	10	250	11	250	17	290*	6	120*	9	250	25	M	M	23
24	300	34G	280	20	290	28	240	12	260	13	190	10	040	8	250	25	240*	6	240*	13	250	30G	270*	8	24
25	310	38G	290	14	180	10	220	19	250	19	220	24	120	10	240	16	240*	10	VAR*	5	250	27	240*	10	25
26	280	30G	280	20	180	11	180	13	260	12	210	26	050	10	180	13	260	18	230	26	240*	23	260	21	26
27	280	12	270	35	VAR	10	250	27	250	13	210	15	140	9	230	12	270	19	230*	15	240*	27	250	35G	27
28	280	30	250	30		0	250	20	180	14	170	12	180	14	250	16	270	14	240*	20	180*	13	M	M	28
29	280	22	M	M	270	18	240	11	180	14	190	10	VAR	8	250	12	270	15	270*	13	270*	16	M	M	29
30	230	10	M	M	260	16	240	12	250	11	050	10	M	M	210	7	290*	13	240*	14	230	45	M	M	30
31	280	19	M	M	270	17	M	M	300	14	M	M	M	M	250	13	M	M	020*	7	M	M	140*	15	31
MONTH MAX	290	38G	270	35	250	30	250	27	250	19	210	28	230	16	250	25	240	25	240	35	230	45	240	37	MAX
AVE		21		15		16		16		13		15		10		12		11		14		22		21	AVE

YEARLY MAX -- 45 MPH ON NOV 30

G INDICATES GUSTINESS. DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

mum Hourly Winds

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT. YEAR 1968

MINIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	M	M	090	3	320	1	270	1	320	2	320	1	140	1		0	320	5	320	4		0	090	1	1
2	M	M	270	1		0	040	4	320	4	320	2	320	1		0	220	3	320	5		0	360	2	2
3	M	M	360	1	360	1		0	040	1	270	1	320	1		0		0		0		0	360	6	3
4	040	1	040	1		0		0	320	4	320	1	220	1		0	320	1		0	090	2	M	M	4
5	090	1	360	1		0	320	1	320	2	320	3	270	1		0	320	2	360	3		0	M	M	5
6	040	3	220	1	090	1	270	5	040	2	180	3	320	1		0	270	1	360	3	320	2	M	M	6
7	090	1	360	1	040	2	320	10	320	13	180	1		0		0	320	6	090	4	090	1	M	M	7
8	040	1	320	1	090	1	320	1	320	5	090	1		0		0	270	5	M	M	090	2	M	M	8
9	090	1		0	320	1	320	1	270	2	320	1		0		0	270	1	320*	1	360	4	M	M	9
10	040	2	090	1	270	1		0	270	1	320	1	320	1		0	220	1	270	1	360	4	M	M	10
11	040	3	320	1	270	1	040	1	270	1	320	4	270	1		0	220	1		0	090	2	M	M	11
12	360	1	360	1		0	320	5	360	1	320	4	320	1	320	1		0		0	320	2	M	M	12
13	360	2	040	1	040	2	360	5	360	3	320	6		0		0		0	090	3	360	1	M	M	13
14	360	3		0	320	6	040	3	040	3	090	1	320	1	270	1		0	360	2		0	M	M	14
15		0	270	2	320	1	320	9	360	6	360	3		0	320	3	320	5	320	2	140	1	M	M	15
16		0	040	3		0	320	3	140	1	360	3	360	2	040	1	320	5	360	2	320	16	M	M	16
17	360	4	320	3	360	4	270	4	320	6	320	6	270	2	320	2	040	4		0	360	6	M	M	17
18		0	320	8	090	3	220	7	090	3	270	6		0	320	6	320	5	040	2	360	2	M	M	18
19		0	320	9	140	1	320	2	320	1	270	1		0		0	270	1	220	1		0	M	M	19
20		0	040	2	180	1	140	1	320	2	320	5	270	1	040	2	040	4	320	2	360	2	M	M	20
21	320	1	360	3	040	3	320	1	090	1		0		0		0		0	090	2		0	M	M	21
22	040	1	320	8	320	5	270	1	360	5	040	2	140	1	320	1		0	040	5	360	1	M	M	22
23	360	1	320	9	360	1	140	2	180	2	270	1	270	1	090	1	360	2	320	13	360	3	M	M	23
24	040	1	320	8	360	4	360	1	320	1	320	2	220	1		0	270	2	320	2		0	M	M	24
25	360	1	040	3	320	3	320	1	360	4	360	2	270	3	320	1		0		0	090	4	M	M	25
26	180	1	320	1	320	8	040	3	320	7	320	10		0	270	1		0	090	3		0	M	M	26
27	180	1	140	1	040	1		0	320	6	320	5		0		0	320	3	320	14		0	M	M	27
28	090	2	040	2	090	1	270	1	270	4	320	6		0		0	270	1	320	6		0	M	M	28
29	360	1	040	3	320	2	320	1	270	2	320	4	270	1		0	270	2		0		0	M	M	29
30	360	3	M	M	270	5	320	4	360	3	320	3	040	1		0	270	1	320	1		0	M	M	30
31	360	4	M	M	220	1	M	M	320	2	M	M		0		0	M	M	090	1	M	M	M	M	31
MONTH MAX	360	4	320	9	320	8	320	10	320	13	320	10	270	3	320	6	320	6	320	14	320	16	360	6	MAX
AVE		01		03		02		03		03		03		01		01		02		03		02		03	AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1969

MINIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	M	M	M	M	320	03	320	02	M	M	M	M	M	M	180	02	040	01	090	03		0		0	1
2	M	M	M	M		0		0	M	M	M	M	M	M	270	01	180	01	090	01	270	04		0	2
3	M	M	M	M		0	360	04	M	M	M	M	M	M	VAR	01	270	01	090	01		0		0	3
4	M	M	M	M		0	270	02	M	M	M	M	M	M	090	01	040	02	090	01		0	090	02	4
5	M	M	M	M		0		0	M	M	M	M	M	M	220	01	090	02	270	02		0		0	5
6	M	M		0	M	M	090	04	M	M	M	M	M	M	090	01		0	VAR	01		0		0	6
7	M	M	270	02	M	M	040	04	M	M	M	M	M	M	270	01	040	01	220	02		0	040	02	7
8	M	M	140	01	M	M	270	01	M	M	M	M	M	M	140	01	040	01	320	01		0	090	02	8
9	M	M	040	01	M	M	040	01	M	M	M	M	M	M		0	VAR	01	090	01		0		0	9
10	M	M	040	02	M	M	140	02	M	M	140	01		0	270	03	220	01		0	090	01	270	01	10
11	M	M	360	01	M	M	040	01	M	M	040*	01	270	02	270	01	VAR	01	090	02	220	02	090	02	11
12	M	M		0	M	M		0	M	M	220	01		0	090	01	090	01		0	090	02	090	02	12
13	M	M		0		0		0	M	M	270	01	090	01	090	01	090	02		0	220	18	090	01	13
14	M	M	040	01		0	220	01	M	M	220	01	VAR	01	270	01	VAR	01	VAR	02	090	03		0	14
15	040	04		0		0	220	01	M	M	180	01		0	270	03		0	VAR	01		0	180	01	15
16	360	01		0		0	040	01	M	M	140	01	180	01	040	02		0	090	01		0	090	01	16
17	090	02	320	02	270	01		0	M	M		0	090	01	090	01		0	090	02		0		0	17
18		0		0	140	03		0	M	M	140	01	320	01	270	01		0	VAR	01	270*	02		0	18
19	090	01	220	02	220	04	M	M	M	M	270	02	M	M		0	040	01	090	01	M	M	VAR	01	19
20	220	03		0		0	M	M	M	M	220	02	M	M		0	360	01	VAR	01	090	01	090	03	20
21	VAR	01	320	03	270	02	M	M	M	M	320	07	M	M	VAR	01	090	01		0		0	270	10	21
22	220*	05	040	01		0	M	M	M	M	270	04	M	M	090	01		0		0		0	270	10	22
23	040	02	140	01	180	03	M	M	M	M	040	02	270*	04	360	01		0		0		0	090	02	23
24		0	040	01	140	01	220	03	M	M	320	01		0		0	270	03	090	01		0		0	24
25	270	03	270	03	220	04	320	08	M	M	M	M		0		0	270	05		0		0	090	01	25
26	220	02	040	02	270	04	320	04	M	M	M	M	270	02	M	M	270	02		0		0	090	01	26
27	VAR	01		0	270	02	320	01	M	M	M	M	090	02	M	M	270	04	090	01		0	270	01	27
28	180	01		0	270	10		0	M	M	M	M		0	M	M	270	04	090	01		0	VAR	01	28
29	M	M	M	M	270	06	270	06	M	M	M	M		0	090	01	090	02	270	01		0	090	01	29
30	M	M	M	M	320	05	M	M	M	M	M	M	270	01	040	01	090	05	270	05		0	090	01	30
31	M	M	M	M	220	09	M	M	M	M	M	M		0	270	01	M	M	220	02	M	M	090	01	31
MONTH MAX	220	05	320	03	270	10	320	08			320	07	270	04	270	03	270	05	270	05	220	18	270	10	MAX
AVE		02		01		02		02				02		01		01		01		01		01		02	AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

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CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1970

MINIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	090	01	M	M	090	01		0		0		0	VAR*	01	VAR	01		0		0	090	01	220	01	1
2	270	01	M	M	VAR	01	270	05	360	03		0	270	01	VAR	01		0		0		0	090	01	2
3	270	03	M	M	VAR	01	VAR	01	320	01		0	140	01	VAR	01	140	06		0	140	01	270	01	3
4	090*	01	M	M	320	01	320	01	180	01	180	02		0	VAR	01		0		0		0	270	01	4
5	M	M	270	04	M	M	320	07	VAR	01		0		0		0	140	01	270	01		0		0	5
6	M	M	320	03	M	M	270	01	220	03		0	VAR	01		0		0		0	320	01		0	6
7	M	M	VAR	01	M	M	VAR	01	220	02	220	01	220	01		0		0		0		0		0	7
8	320	01	090	01	M	M	320	03	090	02	140	01	040	01	*	0		0	270	01	320	09	220	01	8
9	VAR	02	VAR	01	M	M	270	01	270	03	220	01	140	01	M	M	270	01	360	01	270	01		0	9
10	090	04	VAR	01	M	M	320	02	VAR	02	090	01	VAR	01	M	M	VAR	01		0	090	02	320	01	10
11	090	01	090	02	M	M	270	05	VAR	02		0	090	01	M	M	270	09		0		0	320	01	11
12	090	01	090	01		0	320	08	220	02	220	04		0	140*	01	270	05		0		0		0	12
13	VAR	01	270	05	270	05		0	VAR	02	220	04	320	02	VAR	01	180	01		0		0		0	13
14	090	01	090	01	270	03	320	05	VAR	01	VAR	01	270	02	270	01		0		0	270	01	040	01	14
15	090	01	VAR	02	VAR	01	270	06	270	06	090	05	VAR	01		0	VAR	01		0		0		0	15
16	090	01	270	03	VAR	01	220	03	270	01	220	01	180	01		0		0		0		0	VAR	01	16
17	320	05	270	12	270	03	180	03	270	07	140	01		0	270	01		0		0	VAR	01	220	01	17
18	270	09	270	02	040	01	180	03	270	05	VAR	02		0		0		0		0	360	01		0	18
19	090	04	090	01	270	01	320	06	VAR	03	220	01		0		0		0	270	01	VAR	05		0	19
20	090	02		0		0	320	10	270	04		0		0		0	090	02	270	02	VAR	01		0	20
21	270	06		0	VAR	01	180	01	220	01	140	01	270	01	220	01		0	VAR	03	270	18		0	21
22	090	04		0	VAR	01	VAR	02	220	02		0		0	M	M	180	01		0	320	06	270	07	22
23	090	02	220	01	270	06	270	02		0	VAR	01	140	01	M	M	320	01	320	01	320	09		0	23
24	270	10		0	VAR	02	220	02	090	01	180	01	220	01	M	M	270	02	270	01	270	09	270	04	24
25	270	09	270	01	VAR	01	VAR	01	M	M	270	07	140	01	M	M	140	01	270	01	270	05		0	25
26	090	01	180	03	320	01	220	03	M	M	270*	04		0	040*	01		0		0	VAR	01		0	26
27	270	06	VAR	01	180	01	360	02	VAR*	01	M	M		0		0		0		0	090	01		0	27
28	270	09	180	01	VAR	01	040	01		0	M	M	140	01	VAR	01		0	360	04	220	02	270	01	28
29	090	02	M	M	360	01	VAR	01	VAR	01	M	M	VAR	01	270	01		0	270	14	220	01	040	01	29
30		0	M	M	180	07		0	270	03	M	M	270	01	180	01		0	270	10	270	09	320	02	30
31	090	01	M	M		0	M	M	VAR	01	M	M	140	01		0	M	M	270	09	M	M	VAR	02	31
MONTH MAX	270	10	270	12	180	07	320	10	270	07	270	07	320	02	VAR	01	270	09	270	14	270	18	270	07	MAX
AVE		03		02		02		03		02		02		01		01		01		02		03		01	AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

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CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1971

MINIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1		0		0		0	270	10		0	040	02	220	01		0	220	01	M	M	270	02	M	M	1
2		0		0		0	360	01		0	140	02	320	02		0	VAR	01	M	M	270	07		0	2
3	090	01	040	01	270	02	040	01		0	220	01	270	01		0	270	01	M	M	270	02		0	3
4		0	270	03	270	01		0	320	04	090	01	220	02		0	220	10	M	M	040	01		0	4
5	320	01	270	15		0		0		0	040	01		0		0	320	05	M	M	090	03		0	5
6		0	360	02	320	02		0		0	220	01	220	02		0		0	M	M	090	01		0	6
7		0	320	10		0	180	01		0	220	01		0	M	M	360	04	M	M	040	01		0	7
8		0	320	10		0		0		0	VAR	01		0	M	M	VAR	01		0		0		0	8
9	270	04		0	090	01	040	02		0	M	M	220	02	M	M		0		0		0		0	9
10	270	05	270	05	270	03	270	02		0	M	M	220	05	M	M	360	01		0		0		0	10
11	320	02	320	10	360	01	270	09		0	M	M	220	03		0		0		0		0		0	11
12	270	05	320	03	270	01	320	08		0	M	M	220	06	090	01		0	220	01	040	01		0	12
13	270	10	320	02	180	01		0		0	M	M		0		0		0		0		0		0	13
14	320	01		0	270	05	090	02	VAR	01	M	M	220	01		0	220	02		0		0		0	14
15	270	02	090	01	320	08		0	220	01	M	M		0		0	220	01	VAR	02	180	02		0	15
16	270	05	270	01	320	11	320	05	270	01	M	M		0		0	040	04	180	02	VAR	02	270	01	16
17	270	14	270	03	320	05	220	01	270	01	M	M		0	220	01	360	03		0		0	M	M	17
18	320	06		0	320	04	VAR	01		0	M	M	040	01		0	220	01	220	02		0	M	M	18
19	360	01		0	090	01	VAR	01	270	09	M	M		0		0	VAR	01		0		0	M	M	19
20	360	03		0	090	01	320	03	180	02	M	M		0		0	220	01		0	*	0	M	M	20
21		0		0	320	03		0	360	01	M	M	VAR	01		0		0		0	M	M	M	M	21
22	320	05		0	320	10		0	270	01	M	M		0		0	M	M	*	0	M	M	M	M	22
23	090	01		0		0		0		0	270	01	040	01		0	M	M	M	M	M	M		0	23
24	180	04		0		0		0	270	06	270	04		0		0	M	M	M	M	M	M		0	24
25	270	12	180	01	320	10	140	02	360	03	270	03	270	04		0	M	M	M	M	M	M	360	01	25
26	090	05	320	05	320	06	090	01	360	03	220	05	040	01		0	M	M	M	M	M	M	220	01	26
27	270	03	320	07	VAR	01	320	04	270	01	270	02	220	01		0	M	M	M	M	M	M		0	27
28		0		0	090	01	090	01	040	04	360	02		0		0	M	M	180	05	M	M		0	28
29	320	04	M	M	090	02	320	01		0	220	02		0		0	M	M	270	01	M	M		0	29
30	270	12	M	M		0	320	02	320	01		0		0		0	M	M	360	01	M	M	360	01	30
31	270	01	M	M	320	10	M	M	270	01	M	M	140	01	220	01	M	M	040	01	M	M	*	0	31
MONTH MAX	270	14	270	15	320	11	270	10	270	09	220	05	220	06	090	01	220	10	180	05	270	07	270	01	MAX
AVE		03		03		03		02		01		02		01		00		02		01		01		00	AVE

G INDICATES GUSTINESS. DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

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CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1972

MINIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	M	M	M	M	060	1	250	4	260	4	250	1	270	2	300	1	180	1	230	1	180	1	270	3	1
2	M	M	M	M	M	M	180	3	230	2	180	1	180	1	080	1	230	1	020	1	360	1	060	4	2
3	M	M	M	M	M	M	260	3	270	4	230	1	250	1	180	1	180	1	180	1	240	1	250	7	3
4	M	M	M	M	M	M	270	11	300	1	180	1	180	1	180	1	220	1	030	1	VAR	1	330	2	4
5	M	M	M	M	M	M	070	1	180	1	220	1	240	1	060	1	260	1	020	1	080	1	180	1	5
6	M	M	M	M	M	M	260	8	070	1	330	1	280	1	230	1	060	2	VAR	1	240	1	050	1	6
7	M	M	M	M	M	M	270	1	070	1	060	1	260	1	230	1	060	1	200	1	030	1	030	1	7
8	M	M	M	M	M	M	060	1	240	1	180	1	060	1	070	1	050	1	360	1	060	1	180	1	8
9	M	M	M	M	M	M	240	8	070	1	220	1	270	1	180	1	030	1	200	1	060	1	180	1	9
10	M	M	M	M	M	M	270	1	180	1	230	1	250	1	040	1	070	1	VAR	1	050	1	010*	1	10
11	M	M	M	M	M	M	180	2	300	1	270	2	060	1	080	1	180	1	040	1	180	1	060	1	11
12	M	M	M	M	M	M	220	7	270	2	120	1	220	1	270	1	330	1	330	1	VAR	1	240	1	12
13	M	M	M	M	M	M	030	1	230	1	220	1	M	M	180	1	280	1	180	1	230	1	240	1	13
14	M	M	M	M	M	M	040	1	330	1	240	1	M	M	180	1	260	3	220	1	080	1	090	1	14
15	M	M	M	M	240	4	360	1	280	1	270	1	M	M	180	1	260	4	050*	1	180	1	180	1	15
16	M	M	M	M	260	4	360	1		0	100	1	M	M	190	1	330	1	*	0	030	1	330	1	16
17	M	M	M	M	240	6	250	1	180	1	200	1	M	M	070	1	200	5	060	1	060	1	300	1	17
18	M	M	M	M	300	1	180	5	180	4	230	1	270	1	100	1	030	1	050	1	210	1	050	1	18
19	M	M	M	M	250	1	200	1	180	1	180	5	310	1	200	1	240	1	180	1	030	1	080	1	19
20	M	M	M	M	280	1	180	1	010	1	180	1	180	1	050	1	280	1	030	1	020	1	270	9	20
21	M	M	M	M	200	1	270	5	020	1	240	2	180	4	200	1	050	1	300	1	230	1	300	1	21
22	M	M	M	M	030	1	270	5	300	1	180	1	180	2	220	1	060	1	300	1	140	1	030	1	22
23	M	M	M	M	240	2	240	1	160	1	010	1	180	1	220	1	180	2	320	1	240	1	330	1	23
24	M	M	M	M	280	4	240	1	290	3	270	1	180	1	300	1	180	1	VAR	1	330	1	100	1	24
25	M	M	M	M	270	4	280	3	180	3	070	1	210	1	280	1	180	1	040	1	240	2	240	1	25
26	M	M	M	M	280	1	290	4	330	1	180	1	200	1	290	1	270	1	290	1	180	2	330	1	26
27	M	M	M	M	030	1	270	2	180	1	230	4	230	1	030	1	060	1	290	1	050	1	030	1	27
28	M	M	M	M	180	1	260	4	180	1	180	1	090	1	110	1	260	9	270	1	200	1	300	1	28
29	M	M	M	M	230	1	320	1	240	1	030	1	230	1	180	1	290	4	060	2	290	2	320	1	29
30	M	M	M	M	260	9	290	1	060	1	230	1	260	1	240	1	230	1	240	1	270	10	280	2	30
31	M	M	M	M	330	4	M	M	230	2	M	M	280	1	200	1	M	M	240	1	M	M	240	1	31
MONTH MAX					260	9	270	11	260	4	180	5	180	4	300	1	260	9	060	2	270	10	270	9	MAX
AVE						03		03		01		01		01		01		02		01		01		02	AVE

G INDICATES GUSTINESS. DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1973

MINIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	240	1	090	1	360	1	020	1	180	1	M	M	070	2	M	M	180	3	150	3	110	3	130	3	1
2	050	1	030	1	080	1	070	1	020	1	M	M	220	1	M	M	180	3	230	7	210	1	220	4	2
3	070	1	030	1	260	1	240	1	180	2	M	M	180	1	M	M	180	3	230	4	180	2	180	2	3
4	280	1	050	1	050	1	280	1	180	1	M	M	100	2	M	M	250	3	110	3	340	3	280	5	4
5	270	1	020	1	180	1	070	1	180	2	M	M	240	2	M	M	270	3	330	3	070	3	160	3	5
6	220	1	050	1	280	1	330	1	150	2	240	2	190	4	M	M	180	3	180	5	120	3	180	2	6
7	040	1	360	1	230	1	230	1	270	3	240	2	230	2	M	M	180	3	180	3	270	10	360	2	7
8	250	1	060*	1	180	1	230	1	300	2	180	2	080	1	290	4	360	4	M	M	290	8	330	4	8
9	030	1	M	M	030	1	260	6	270	2	180	1	120	1	220	2	180	5	M	M	110	2	230	2	9
10	320	1	M	M	180	1	270	1	220	11	180	1	060	1	270	1	180	3	M	M	240	2	180	3	10
11	070	1	M	M	200	1	240	1	260	1	200	2	060	1	060	1	180	3	M	M	260	3	030	3	11
12	360	1	M	M	060	1	280	1	180	1	210	1	020	1	180	1	180	2	M	M	320	2	240	1	12
13	030	2	M	M	030	3	180	1	190	1	140	1	300	1	220	1	230	4	M	M	180	3	090	1	13
14	180	1	360	1	280	1	180	2	080	1	120	1	050	1	240	4	170	3	M	M	240	7	280	7	14
15	230	1	330	1	320	1	030	1	200	1	180	2	330	1	270	2	180	3	M	M	180	3	250	2	15
16	050	1	040	1	040	1	260	2	190	1	180	2	190	1	180	4	280	5	240*	5	130	3	040	2	16
17	240	1	030	1	360	1	090	1	230	2	180	2	060	1	360	4	170	3	260	2	210	4	360	1	17
18	180	1	030	1	050	1	180	2	210	2	250	4	070	1	180	3	300	8	290	3	180	2		0	18
19	030	1	050	1	200	1	250	9	210	3	280*	1	090	1	180	2	090	3	180	1	180	3	M	M	19
20	250	1	180	1	270	1	180	1	210	2	230	2	180	1	170	3	300	3	180	3	180	2	M	M	20
21	220	1	030	1	020	1	230	1	020	1		0	240	1	210	2	090	2	240	3	270	2	M	M	21
22	240	1	250	2	270	1	230	1	050	1	180	1	060	1	330	3	180	2	060	3	190	2	M	M	22
23	240	1	310	1	030	1	060	1	220	6	330	2	060	2	270	2	210	5	110	5	200	2	M	M	23
24	050	1	350	1	310	1	030	1	230	9	230	5	030	1	180	3	090	4	180	2	060	2	M	M	24
25	070	1	330	1	220	1	060	1	220*	2	220	2	M	M	290	4	250	3	110	3	230	3	M	M	25
26	050	1	060	1	070	1	360	1	M	M	270	3	M	M	180	3	120	2	230	2	280	2	M	M	26
27	010	1	050	1	330	1	280	1	M	M	210	1	M	M	300	4	220	2	280	4	300	6	M	M	27
28	060	1	030	1	080	1	020	1	M	M	210	1	M	M	180	3	180*	4	230	3	180	3	M	M	28
29	180	1	M	M	190	1	300	1	M	M	270	2	M	M	180	3	180	2	200	3	180	3	M	M	29
30	230	1	M	M	210	1	180*	2	M	M	360	1	M	M	180	3	290	2	100	2	190	2	M	M	30
31	050	1	M	M	220	1	M	M	M	M	M	M	M	M	150	4	M	M	250	21	M	M	M	M	31
MONTH MAX	030	2	250	2	030	3	250	9	220	11	230	5	190	4	290	4	300	8	250	21	270	10	280	7	MAX
AVE		01		01		01		02		02		02		01		03		03		04		03		03	AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR - VARIABLE DIRECTION
HR - WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1974

MINIMUM HOURLY WINDS - MPH

DAY	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	JUN DIR	JUN SPD	JUL DIR	JUL SPD	AUG DIR	AUG SPD	SEP DIR	SEP SPD	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	DAY
1	M	M	280	5	180	2	280	9	280	5	010	1	210	3		0	180	1	260	5		0	M	M	1
2	M	M	240	1	M	M	090	2	190	2	M	M	210	3		0		0	250	3		0	M	M	2
3		0	280	2	M	M	260	2	200	1	M	M	230	1		0		0		0		0	M	M	3
4		0	180*	3	M	M	220	2	180	1	M	M		0		0		0	230	5		0		0	4
5	110	2		0	240	1	280	2	230	1	M	M		0		0	280	4	320	1		0		0	5
6	230	16		0	070	2	240	5	280	3	M	M		0	220	2	230	3		0		0	310	2	6
7	240	2		0	240	2	290	9	280	10	M	M		0	120	2	250	1	280	4		0		0	7
8	180	1	300	2	200	1	030	1	120	4	M	M		0	200	2		0		0		0		0	8
9		0		0	300	2	100	3	230	3	M	M	M	M	150	3	120	1		0		0		0	9
10	300	1		0	180	1	130	3	250	2	M	M	M	M	300	3	280	5		0		0		0	10
11		0		0	270	1	180	6	240	12	270	6	180	1	300	6	150	1		0	180	1		0	11
12	080	1	100	1		0		8	250	7	180	2		0	310	1		0		0	310	9	340	5	12
13	110	1		0	070	1	220	2	220	4	250	2		0	180	1		0		0	330	10		0	13
14	180	1		0	180	5	230	3	260	2	360	1	150	1	190	2		0		0	300	8	180	5	14
15	090	1		0	330	3	230	8	220	13	180	1		0	230	5		0		0	360	4	320	5	15
16		0		0	320	5		0	200	9	180	1		0	230	4		0		0		0	320	6	16
17		0	100	1	260	10	220	2	210	5	110	1		0	270	1	180	2		0		0		0	17
18		0	VAR	1	280	3	170	3	220	3		0		0	100	1		0		0	330	1	170	1	18
19	360	1		0	020	2	180	3	180	4		0		0	180	1		0		0	260	1	300	2	19
20		0		0	060	2	200	2	240	4	180	9		0	180	2		0		0	320	1	340	10	20
21	300	1		0	270	5	M	M	270	4	M	M		0	180	1		0		0		0	180	4	21
22	300	2		0	260	7	M	M	120	1	M	M		0	180	3		0		0		0		0	22
23		0	270	1	070	5	180	3		0	M	M		0		0		0	020	1	*	0		0	23
24		0		0		0	180	3		0	M	M		0		0		0		0	M	M		0	24
25		0		0	230	11	020	2	070	2		0		0		0		0		0	M	M		0	25
26	250	1	050	1	270	3	160	3	240	6	310	2		0		0		0		0	220	1		0	26
27		0	230	2	280	4	170	2	280	3		0		0	180	1	300	3		0		0		0	27
28	110	1	310	2	360	4	180	2	170	5	290	2		0		0	320	4		0	M	M		0	28
29	290	5	M	M	280	20	270	1	190	9	240	2		0	300	4		0	180	1	M	M		0	29
30	110	5	M	M	230	2	180	1	090	1	220	1		0	300	4	300	1	280	2	M	M		0	30
31	220	1	M	M	230	3	M	M	330	1	M	M		0	250	7	M	M	290	1	M	M		0	31
MONTH MAX	230	16	280	5	280	20	280	9	220	13	180	9	210	3	250	7	280	5	260	5	330	10	340	10	MAX
AVE		01		01		04		03		04		02		00		02		01		01		01		01	AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR - VARIABLE DIRECTION
HR - WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
FRASER EXP. FOREST WIND TOWER

FOOL CREEK - ELEV. 10,620 FT.

YEAR 1975

MINIMUM HOURLY WINDS - MPH

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1		0		0	VAR	1		0		0	280	5		0	M	M		0	M	M	M	M	VAR*	7	1
2	VAR	1		0		0	VAR	1		0	VAR	1		0	M	M		0	VAR*	1	*	0	240	5	2
3		0		0	250	3		0	190	5	VAR	1		0	M	M		0	M	M	300*	1	M	M	3
4		0		0		0	VAR	4	190	3		0		0	M	M		0	VAR	2	M	M	M	M	4
5		0		0		0		0	VAR	1		0		0	M	M		0	VAR	2	M	M	VAR*	2	5
6	VAR	1	M	M		0	VAR	3	VAR	2		0	*	0	M	M		0	M	M	M	M	VAR	1	6
7	180	1	M	M		0	M	M		0	VAR	1	M	M	M	M		0	VAR	2	M	M	VAR	2	7
8		0	M	M		0	M	M		0		0		0	M	M		0	VAR*	2	M	M	270	7	8
9		0	M	M		0	M	M	VAR	1		0		0	M	M	180*	1	VAR*	1	M	M	260	2	9
10	330	2	M	M		0	M	M	210	1		0		0	M	M	VAR*	1	M	M	M	M	VAR	1	10
11	310	15		0		0	M	M	290	2	210	4		0	M	M	VAR*	1	M	M	M	M	VAR*	1	11
12		0		0		0	M	M		0	230	8		0		0	M	M	M	M	M	M	VAR*	1	12
13	180	2		0		0	M	M	280	4	230	10		0		0	M	M	M	M	M	M	M	M	13
14	VAR	3		0		0	M	M	VAR	1	250	10		0		0	M	M	260	3	M	M	VAR	1	14
15		0		0		0	M	M		0	240	8		0		0	M	M	*	0	M	M	VAR	1	15
16	VAR	2		0		0	M	M	VAR	2	VAR	1		0		0	VAR*	1	VAR	2	M	M	250	15	16
17		0		0		0	M	M		0		0		0		0	220	13	VAR*	1	M	M	VAR	1	17
18	180	1		0	VAR	1	M	M		0	VAR	4		0	VAR	1	VAR	3	330*	1	M	M	M	M	18
19	VAR	2		0	250	5	M	M		0		0		0	VAR	1	260	2	210*	1	*	0	M	M	19
20	VAR	2	VAR	1	150	3	M	M	180	5		0		0		0	*	0	230*	1	M	M	M	M	20
21		0		0	290	4	M	M	180	5		0		0		0	VAR*	1	180*	1	M	M	M	M	21
22		0		0	270	7	210	5		0		0		0		0	M	M	200*	1	M	M	M	M	22
23	VAR	2		0	290	13	VAR	2	290	1		0		0	210	2	VAR*	1	180*	1	VAR	1	M	M	23
24	VAR	7		0	290	5		0	VAR	2	180	3		0	VAR	2	VAR*	1	240*	1	240	6	VAR*	1	24
25	290	26		0		0	210	8		0	VAR	2		0		0	280*	1	VAR*	1	VAR	1	VAR*	1	25
26	260	14		0		0	180	5		0		0		0		0	240	7	090	1	VAR*	1	270	3	26
27		0	320	6		0	VAR	2		0	VAR	1		0		0	270	7	360*	1	030*	1	240	6	27
28		0	VAR	2		0	250	5		0	VAR	1		0		0	260	3	180*	1	*	0	M	M	28
29		0	M	M		0		0		0		0		0		0	VAR	4	VAR*	1	VAR*	1	M	M	29
30		0	M	M		0	220	5		0		0	M	M		0	VAR*	1	180*	2	VAR	3	M	M	30
31		0	M	M		0	M	M	VAR	1	M	M	M	M		0	M	M	*	0	M	M	VAR*	1	31
MONTH MAX	290	26	320	6	290	13	210	8	190	5	230	10		0	210	2	220	13	260	3	240	6	250	15	MAX
AVE		03		00		01		03		01		02		00		00		02		01		01		03	AVE

G INDICATES GUSTINESS. DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
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Chairlift—Elevation 11,880 Feet

Prevailing Wind Direction and Mean Daily Windspeed

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1963-64

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	W	11	N*	9	W	14	W	16	W	16	W	12	W	13	SW*	9*	1
2	SW*	7*	N*	9	N*	11	W	20	NE	11	S	16	NW	17	S	14	2
3	W*	10	W*	9	N	8	N	10	S	8	N*	14	S	13	SW	28	3
4	SW*	8	M	14	N*	8	W	15	N	10	NW	23	S	13	SW	24	4
5	W*	9	W	14	W	8	W	14	N	13	W	15	W	14	S	26	5
6	W*	7*	W	19	W	17	W	15	NW	M	W*	9	S*	9	S	14	6
7	S*	7	SW	14	W	24	W	13	W*	22*	S	7	N*	8	S	18	7
8	SW*	9	W*	14	W	14	N*	13	M	23	N*	9	N*	9	NW	15	8
9	W	8	M	18	S	14	W	21	M	24	N	13	N	10	M	M	9
10	W*	11*	W*	11	S	13	NW	16	N	18	W	14	W	14	M	M	10
11	S	11	W*	12	N	9	NW	16	W	15	W	18	W	19	M	M	11
12	S	11	W*	15	W	19	N	8	S	11	SW	26	NW	27	M	M	12
13	VAR	9	M	7	W	24	N	13	N*	7	SW	13	W	35	M	M	13
14	NE*	7	W*	12	W	18	N*	8	N*	13	W*	21*	W	24	M	M	14
15	NE*	5	SW*	11	W	16	N*	9	N	14	W	16	VAR	14	M	M	15
16	S*	M	SW*	14	W	12	NW	21	W	12	N	10	SW	30	M	M	16
17	W*	8	M	11	W	26	SW	22	W*	19*	N*	12	S	17	M	M	17
18	NE*	8	M	6	N*	12	SW	23	M	M	W	11	S	16	M	M	18
19	S*	8	M	7	W	13	M	22	W	14	N	19	S	16	M	M	19
20	M	7	SW*	13	N*	9	M	27*	NW	11	N	14	W	16	M	M	20
21	M	11	M	19*	E*	7*	M	M	NW	17	W	17	W	16	M	M	21
22	N*	10	M	19*	N	11	S	14	N	14	S	25	W	18	M	M	22
23	N	12	M	9	N	16	W	20	N	13	M	M	S	18	M	M	23
24	N	9	M	7	N	13	M	21	SW	13	M	7*	S	15	M	M	24
25	W*	8	M	8	W	15	W	15	NW	13	W	21	W	15	M	M	25
26	SW	11	M	9	W	12	W	13	N	14	W	16	NW	25	M	M	26
27	W*	10	M	9	W*	20*	W	13	NW	20	W	19	NW	32	M	M	27
28	W*	9	W	17	W	18	W	13	W	11	W	18	NW	13	M	M	28
29	W*	10*	W	18	NW	21	N	7	M	15	W	17	E	10	M	M	29
30	SW*	18*	W	13	NW	16	N	11			M	15	N*	8	M	M	30
31	N*	7			N	16	W	19			W	11			M	M	31
MONTHLY MAX	SW	18	W	19	W	26	M	27	W	24	SW	26	W	35	SW	28	MAX
AVE		09		12		15		16		15		15		17		**	AVE

YEARLY MAX -- W 35 MPH ON APR 13

VAR = VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1964-65

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	SW	M	W	13	N*	M	W	18	E*	10	S*	17	SW	19	1
2	M	M	NW*	M	N	10	N*	11	W	17	M	7	S	14	S	24	2
3	M	M	NW*	11*	N	6	W	17	W	29	N	20	W*	9	M	M	3
4	M	M	S*	M	N*	6	W*	10	W	16	N	15	S	12	M	M	4
5	M	M	NW*	M	NW*	7	W	20	W	12	N*	7	W*	14	M	M	5
6	M	M	NW	12	N*	7	SW	21	VAR*	10	N*	5	W*	16	M	M	6
7	M	M	NW	10	N	7	SW	25	S*	10	N*	9	S	14	M	M	7
8	M	M	W	14	N*	11	M	M	S*	8	N*	12	S	13	M	M	8
9	M	M	SW	14	N*	9	W*	12	N*	10	W*	12	S	22	M	M	9
10	M	M	W*	16	NW	12	SW*	14	S	18	W	13	W*	16	M	M	10
11	M	M	N*	17	SW*	21	W*	6	N	15	W*	9	N	14	M	M	11
12	M	M	W	17	W	17	W	17	NW	21	N*	8	S	19	M	M	12
13	M	M	SW	16	W	31	W	24	N	18	W*	13	S	25	M	M	13
14	M	M	S	16	W	14	W	27	N	14	W	16	W	17	M	M	14
15	M	M	S	18	SW	32	NW	26	N*	11	W*	13	W	16	M	M	15
16	M	M	SW	19	SW	31	N*	10	N	14	W*	17	SW	21	M	M	16
17	M	M	S*	11	W	15	N*	10	N*	10	N	19	SW	24	M	M	17
18	M	M	N*	6	W*	13	N	8	N	8	W	16	W	18	M	M	18
19	M	M	N*	23	N*	14	N	10	N	9	N	14	W	22	M	M	19
20	M	M	M	16	SW	22	N	10	W	21	W	24	W	18	M	M	20
21	M	M	M	8	W	15	N*	8	W	19	W	23	S	17	M	M	21
22	M	M	M	8	S	33	N	19	SW	21	S	23	S*	15	M	M	22
23	M	M	M	13	SW	30	N	23	N*	16	W*	15	S*	18	M	M	23
24	M	M	NW	19	W	29	S	21	W	27	W	10	NW	11	M	M	24
25	N	10*	W	19	W	24	N	17*	W	23	W*	13	E*	12	M	M	25
26	W	M	SW	26	W	13	W	25	W*	14	S	23	E	12	M	M	26
27	NW	M	W	13	S*	20	W	20	W	15	S	24	NE*	11	M	M	27
28	W	12	W	19	W*	17	W	26	N*	14	N*	13	M	M	M	M	28
29	W	9	NW	22	W*	17	W	26			W*	10	N*	10*	M	M	29
30	SW	17*	W	20	S	17	W	30			N*	10	W*	13	M	M	30
31	NW	13*			S	12	W	27			W	11			M	M	31
MONTHLY MAX	SW	17	SW	26	S	33	W	30	W	29	W	24	S	25	S	24	MAX
AVE		**		15		17		17		16		14		16		**	AVE

YEARLY MAX -- S 33 MPH ON DEC 22

VAR = VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1965-66

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	N*	9	N*	8	W	9	N*	10	SW	23	NW	20	N*	11	1
2	M	M	N	10	N	14	M	M	M	12	SW	16	NW	21	M	9	2
3	M	M	N	7	W	20	W*	16*	NW*	17	N	26	N	10	S*	11	3
4	M	M	N*	9	NW	17	W	11	W	13	N	27	N	15	S*	8	4
5	M	M	N*	8	W	11	N	10	W*	10	N	15	NW	23	M	9	5
6	M	M	N*	6	W	9	NW	19	W*	11	N	10	NW	19	M	M	6
7	M	M	N*	8	W	7	W	20	S*	7	N	15	NW*	18*	M	M	7
8	M	M	S	9	W	6	W	22	S*	14	NW	14	NW	11	M	M	8
9	M	M	W	9	S*	6	W	21	W*	9	W	12	NW	16	M	M	9
10	M	M	W	9	S	13	W	12	W*	10	NW	11	VAR*	10	M	M	10
11	M	M	W	15	N	21	W	18	N	14	N	11	NW*	7	M	M	11
12	M	M	W	11	N	12	N*	15	N*	11	N	9	NW*	11	M	M	12
13	M	M	M	M	S*	5	N	12	W	15	N	9	M	8*	M	M	13
14	W*	M	W	15	W*	9	N	12	W	15	N	11	M	M	M	M	14
15	W	M	W	18	S*	7	N	12	N*	13	NW	14	NW*	13	SW*	M	15
16	S	11	W	9	W*	8	N*	6	N	21	S	34	NW*	13	SW	14	16
17	S	11	W	20	W*	5	N*	8	N	23	N	22	S*	15	NW	13	17
18	N	16	W	12	N*	10	S*	7	W	15	NW	19	S*	20	NW	13	18
19	NW	15	W	14	N	19	N*	8	SW	11	NW	18	S*	11	NW	14	19
20	N	12	W	13	N*	21	W*	9	N	16	S	18	NW*	15	NW	17	20
21	N	10	W	16	W	16	N*	12	N*	7	S	23	S	12	SW	14	21
22	N	11	W	10	S	19	N	8	N*	6	N*	18	S*	7	SW	21	22
23	N	8	SW	20	N*	12*	N	7	N	8	N	18	NW*	11	NW*	11*	23
24	NW	13	SW	20	W*	14*	W	14	S	7	NW*	13	S*	8	N*	9	24
25	W	7	SW	13	W	32	N	20	N	8	N	10	NW*	11	N*	9	25
26	W	10	M	M	W	20*	W	15	N	7	N*	12	S	21	M	7	26
27	W	7	W*	18*	W	14	W	8	N	15	N*	9	NW	18	M	7	27
28	N	9	N	17	W	16	W	18	N	20	N	9	S*	17	SE*	9	28
29	N	11	N	13	W	40	W	14			N	16	VAR*	15	SW*	9	29
30	N*	10	N*	6	W	25	W*	8			N	13	NW	11	SW*	9	30
31	W	8			W	17	N*	13			N	18			SW*	11	31
MONTHLY MAX	N	16	W	20	W	40	W	22	N	23	S	34	NW	23	SW	21	MAX
AVE		**		12		15		13		12		16		14		11	AVE

YEARLY MAX -- W 40 MPH ON DEC 29

VAR = VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1966-67

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	M	M	W	12	NW	15	N	7	W*	21	SW	20	N	22	1
2	M	M	M	M	M	M	NW	13	N	10	SW	19	SW	13	NW	9	2
3	M	M	M	M	W	19	W	16	NW	14	SW	20	SW	16	NW	10	3
4	M	M	M	M	W	7	W	13	NW	21	SW	13	W	15	W	12	4
5	M	M	M	M	W	25	SW	16	W	16	SW	10	SW	19	SW	13	5
6	M	M	M	M	W	16	NW	24	NW	15	W	17	W	10	N	19	6
7	M	M	M	M	W	16	N*	12	NW	16	W	15	SW	11	NW	27	7
8	M	M	M	M	W	13	N	9	N	13	W	18	W	15	NW	21	8
9	M	M	M	M	W	14	N	8	W	24	W	17	M	M	W	15	9
10	M	M	M	M	NW	17	N	8	NW	23	SW	19	S*	15*	SW	17	10
11	M	M	M	M	N	8	N	13	W	19	SW	21	S	19	SW	12	11
12	M	M	M	M	NW	10	NW	9	W	13	SW	21	S	13	S	13	12
13	M	M	M	M	NW	14	W	12	SW	18	SW	24	NW	29	N	12	13
14	M	M	M	M	NW	12	SW	28	SW	23	SW	16	W	21	N	14	14
15	M	M	M	M	NW	7	SW	19	W	17	SW	9	SW	21	NW	20	15
16	M	M	M	M	NW*	9	W	16	W	17	W	11	W	18	N	15	16
17	M	M	M	M	NW	5	M	8	W	27	W	10	S	11	NW	13	17
18	M	M	M	M	N	9	W	15	SW	19	SW	13	S	14	NW	16	18
19	M	M	M	M	NW	9	M	12	N	10	W	14	S	24	W	14	19
20	M	M	M	M	W	10	M	13	N	12	W	10	W	15	N	11	20
21	M	M	M	M	SW	9	M	11	W	22	W	11	W	15	N	10	21
22	M	M	M	M	N	11	M	29	W	20	W	11	SW	12	N	12	22
23	M	M	W*	9	N	4	M	16	W	18	W	11	W	12	SW	11	23
24	M	M	W	17	N	7	M	12	NW	15	M	13	W	14	SW	11	24
25	M	M	W	18	NE	5	M	9	SW	12	M	9	NW	11	M	M	25
26	M	M	W	19	S	8	M	8	N	16	W	13	W	11	M	M	26
27	M	M	W	18	SW	11	M	15	N	11	NE	8	W	17	M	M	27
28	M	M	W	12	SW	13	M	8	NW	13	SW	23	W	18	M	M	28
29	M	M	W	12	N	9	M	7			SW	31	SW	29	M	M	29
30	M	M	W	12	S	6	M	15			W	21	NW	22	M	M	30
31	M	M			NW	15	SW	8			SW	19			M	M	31
MONTHLY MAX			W	19	W	25	M	29	W	27	SW	31	NW	29	NW	27	MAX
AVE		**		**		11		13		16		16		16		14	AVE

YEARLY MAX -- SW 31 MPH ON MAR 29

VAR - VARIABLE DIRECTION
* = LESS THAN OR HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1967-68

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	M	M	W	M	M	M	NW	21	N	8	SW	7	N	9	1
2	M	M	M	M	W	M	M	M	W	14	SW	6	S	13	W	10*	2
3	M	M	M	M	W	M	NW	22	N	12	NE	7	N	18	W	12	3
4	M	M	M	M	N	M	NW	13	N	7	N	10	N	11*	W	12	4
5	M	M	M	M	N	M	W	13	N	7	N	4	W	13	W	11	5
6	M	M	M	M	W	M	NW	17	NW	6	N	7	SW	18	W	17	6
7	M	M	M	M	W	M	W	10	N	9	N	10	NW	16	W	21	7
8	M	M	M	M	W	M	NW	12*	NW	8	S	7	W	8	W	12	8
9	M	M	W	7	N	12	W	M	N	6	S	6	NW	13	SW	8	9
10	M	M	W	15	N	13	W	M	N	6	S	8	N	9	N	8	10
11	M	M	W	11	W	22	NE	11	NW	11	S	12	W	8	S	8	11
12	M	M	W	10	W	16	NW	11	S	15	N	14	W	11	S	7	12
13	M	M	W	12	W	24	NW	14	SW	7	SW	20	SW	21	W	14	13
14	M	M	W	12	W	12	NW	12	W	7	W	12	W	20	SW	22	14
15	M	M	W	14	W	16	N	4	NW	9	W	14	W	17	W	18	15
16	M	M	W	14	W	21	W	6	NW	14	SW	17	SW	10	NW	13	16
17	M	M	W	8	NW	16	N	11	W	16	SW	19	S	12	W	14	17
18	M	M	W	11	W	20	N	9	NW	19	W	14	S	15	NW	13	18
19	M	M	W	13	W	12	N	8	NW	25	S	7	NW	13	NW	10	19
20	M	M	W	18	W*	14	N	6	NW	16	N	5	S	13	W	9	20
21	M	M	M	M	NW	20	N	5	NW	16	NW	20	SW	11	M	M	21
22	M	M	M	M	NW	21	N	6	NW	18	NW	22	SE	7*	M	M	22
23	M	M	M	M	NW	16	N	11	NW	17	N	7	N	10	M	M	23
24	M	M	M	M	NW	19	NE	9	W	16	NW	16	W	9	M	M	24
25	M	M	M	M	NW	18	SW	7	W	13	W	11	NW	11	M	M	25
26	M	M	M	M	NW	17	W	9	NW	11	SW	24	NW	9	M	M	26
27	M	M	M	M	NW	19	SW	16	N	7	NW	11	N	5	M	M	27
28	M	M	M	M	N	13	SW	19	N	18	NW	13	NW	8	M	M	28
29	M	M	M	M	NE	7	SW	15	N	13	W	10	N	6	M	M	29
30	M	M	M	M	NW	9	SW	26			W	12	W	11	M	M	30
31	M	M			NW	20	SW	14			W	7			M	M	31
MONTHLY MAX			W	18	W	24	SW	26	NW	25	SW	24	SW	21	SW	22	MAX
AVE		**		**		16		12		13		12		12		12	AVE

YEARLY MAX -- SW 26 MPH ON JAN 30

VAR - VARIABLE DIRECTION
* = LESS THAN OR HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1968-69

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	NE	6	NW	12	W	20	SW	16	SE	10	NW°	12°	SW	10	1
2	M	M	N	9	NW	17	NW	14	W	26	NE	9	SW	8	S°	12	2
3	M	M	W	9	NW	26	NE	9	W	11	S	7	SW	16	S	9	3
4	M	M	SW	15	W	26	NW	14	SW	10	S	13	N	11	SE	8	4
5	M	M	N	8	W	18	W	26	W	12	NE	10	N	6	E	7	5
6	M	M	NW	9	W	13	W	28	SW	13	SE	8	S	25	E°	17	6
7	M	M	NE	8	W	13	SW	27	N	13	SE	14	W	22	M	15°	7
8	M	M	NW	17	W	13	W°	18	NE	10	NE	7	NW	17	M	20°	8
9	N°	7	NW	24	NW	8	SW	11	W	10	W	8	NE	10	M	M	9
10	W	8	NW	25	W	12	SW	18	W	13	S	7	S	8	M	M	10
11	S°	6°	M	17	SW	27	SW	14	NW	15	S	10	S	7	NW	M	11
12	W	10	SW	21	NW	31	NW	10	W	9	NW	12	NE	5	W	M	12
13	SW	9	S	8	NE	15	E	8	NE	10	W	9	E	5	W	M	13
14	SW	19	NE	5	W	9	E	M	NE	8	S	6	W	11	NW	9°	14
15	SW	16	W	11	SW	16	SW	12	NE	5	N	7	SE	13	SW	9	15
16	N	16	SW	25	SW	15	SW	13	NE	3	N	5	S	8	NE	8	16
17	N	14	NW	20	NE	13	M	14	NW	9	W	9	N	15	W°	9	17
18	N	8	NW	22	N	18	NW	8	S	11	W	17	N	9	W	12	18
19	W	9	NE	12	S	11	N	14	S	13	NW	20	W	9	W	12	19
20	W	12	NW	16	S	9	N	10	W	11	W	9	W	18	SW	13	20
21	M	13	N	7	S	12	SW	9	N	9	W	10	W	10	SW	9	21
22	W	19	NW	16	NW	24	N	17	SW	12	S	10	S	12	SW	10	22
23	NW	23	W	11	W	13	W	16	S	8	N	15	S	12	SW	9	23
24	N	11	SW	17	N	12	SW	10	SW	23	N	11	SW	16	NW	7	24
25	NE	6	N	13	SW	32	SW	19	SW	27	NW	20	W	18	W	6	25
26	W	21	N	4	SW	10	SW	21	SW	21	NW	19	NW	16	SW	6	26
27	NW	21	NE	8	NW	13	SW	15	NW	13	NW	21	N	16	SW	8	27
28	N	11	NE	4	W	16	S	14	SW	11	W	19	M	9	SE°	9	28
29	W	9	NE	12	W	18	SW	14			W	18	SW	12	SW	5	29
30	SW	11	N	9	W	27	SW	22			W	11	SW	15	SW	11	30
31	W	9			W	26	W	20			M	M			W	9	31
MONTHLY MAX	NW	23	NW	25	SW	32	W	28	SW	27	NW	21	S	25	M	20	MAX
AVE		13		13		17		15		13		12		12		10	AVE

YEARLY MAX -- SW 32 MPH ON DEC 25

VAR - VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1969-70

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	M	M	SE	5	N	11	NW	23	SW	12	NW	16	NW	9	1
2	M	M	M	M	NE	8	N	19	NW	23	SW	19	W	14	NW	13	2
3	M	M	M	M	S	12	W	22	W	24	W	8	N	8	N	9	3
4	M	M	W	11	N	14	SW	20	W	20	W	11	NW	13	W	8	4
5	M	M	NE	8	E	7	N	14	W	17	N	5	NW	20	SW	7	5
6	M	M	N	9	N	14	W	16	NW	19	NW	12	N	8	SW	9	6
7	M	M	S	11	N	15	W	28	NW	16	NW	15	W	12	W	12	7
8	M	M	S	7	NW	15	W	20	NW	17	M	12	W	14	W	14	8
9	M	M	SW	7	E	7	NW	16	NW°	12°	SW	12	N	5	W	16	9
10	M	M	NW	13	NW	18	NW	23	NW	14	SW	9	W	13	SW	22	10
11	M	M	NW	16°	W	19	NW	17	NW	11	NE	6	SW	18	SW	18	11
12	M	M	NW	M	W	15	NW	18	M	14	N	12	NW	16	SW	14	12
13	M	M	NW	31	W	14	W	18	M	17	NW	19	S	10	SW	13	13
14	M	M	N	25	NW	11	NW	16	N	8	NW	16	S	19	N	11	14
15	M	M	NW	13	SW	8	N	12	N	15	W	6	SW	13	NW	16	15
16	M	M	SW	16	SW	13	SW	14	W	21	N	10	S	11	NW	14	16
17	M	M	N	17	W	11	NW	19	SW	24	SW	13	S	17	W	13	17
18	M	M	NW	19	W	7	NW	21	NW	14	N	14	NW	16	SW	12	18
19	M	M	NW	17	W	7	M	27	N	7	M	M	M	12	SW	15	19
20	M	M	E	14	W	24	NW°	22	S	9	N	7	W	19	SW	14	20
21	M	M	W	10	SW	17	W	22	N	9	NW	12	S	14	SW	12	21
22	M	M	N	9	W	25	W	25	S	11	NW	16	W	14	SW	10	22
23	M	M	E	7	SW	16	NW	23	SW	6	NW	21	W	10	W	8	23
24	M	M	W	15	W	19	SW	29	S	6	W	22	W	13	W	10	24
25	M	M	S	9	SW	14	SW	22	N	10	N°	19	W	17	M	M	25
26	M	M	W	13	SW	17	SW	18	NW	15	NE	11	SW	23	M	M	26
27	M	M	NE	10	SE	6	SW	26	W	7	S	10	SW	15	M	M	27
28	M	M	E	7	S	12	NW	19	SW	9	NE	M	NE	14	M	M	28
29	M	M	E	8	N	11	NW	21			SE	7	N	9	M	M	29
30	M	M	NE	9	N	15	W	12			SE	21	N	10	M	M	30
31	M	M			N	14	W	12			SW	10			M	M	31
MONTHLY MAX			NW	31	W	25	SW	29	W	24	W	22	SW	23	SW	22	MAX
AVE		°°		13		13		19		14		12		14		12	AVE

YEARLY MAX -- NW 31 MPH ON NOV 13

VAR - VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1970-71

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	N	16	SW	20	SW	9	NW	7	E	M	W	22	W	11	1
2	M	M	N	13	SW	30	S	18	SW	13	M	M	W	17	S	11	2
3	M	M	N	13	SW	23	S	19	NE	15	M	M	N	15	S	8	3
4	M	M	SW	5	SW	18	NW	10	NW	20	M	M	NW	13	S	14	4
5	M	M	NW	13	NW	14	NW	12°	NW	21	NW	M	N	16	NW	14	5
6	M	M	W	12	W	9°	N	M	W	19	M	M	NE°	10	SE	11	6
7	M	M	SW	13	W	10	NE	M	NW	22	M	M	SW	15	SE	7	7
8	M	M	N	31	SW	18°	W	18°	N	23	M	M	NW°	12°	S	10	8
9	M	M	NW	20	SW	M	W	15	N	18°	M	M	M	M	NW	17	9
10	M	M	W	18	N	15°	W	21	W	27	M	M	M	M	N	17	10
11	M	M	N	14	N	11	SW	25	NW	27	M	M	SW°	21°	NE	8	11
12	M	M	W	11	W	M	SW	29°	NW	20	W	17	M	M	N	9	12
13	M	M	N	13	W	M	SW	24	W	19	SW°	16	M	M	W	10	13
14	M	M	N	20	W	M	W	19	NW	13	M	24	M	M	W	10	14
15	M	M	N	10	N	M	W	19	W	13	M	M	M	M	SW	11	15
16	M	M	NW	13	SW	M	W	17	M	17	M	M	M	M	S	18	16
17	M	M	NW	14	SW	M	W	18	SW	14	SW	22	S	13	N	14	17
18	M	M	W	10	SW	12	N	20	NW	14	N	24	SE	15	N	10	18
19	M	M	NW	20	SW	17	NW	22	SE	13	NW	20	E	18	W	16	19
20	M	M	SW	21	SW	10	M	21	S	22	W	18	W	16	S	13	20
21	M	M	SW	31	SW	13	SW	22	SW	11	W	15	W	15°	S	13	21
22	N	10	SW	18	W	21	W	19	N°	9	M	16	N	3	S	14	22
23	N	15	W	24	N	15	NW	17	N	12	SW	18	S	6	N	18	23
24	W	16	W	17	W	22	NW	21	NW	15	NW	20	M	11	W	19	24
25	SW	19	SW	30	NW	14	W	20	M	21	W	18	M	14	SW	10	25
26	N	9	SW	16	SW	9	NW	21	NW	27°	SW	29	M	11	S	11	26
27	N	14	SW	13	W	16	NW	18	NW	M	SW	24	M	17°	S	13	27
28	NW	23	SW	20	W	M	NW	20	SW	M	W	15	SW	11°	S	17	28
29	NW	26	SW	23	SW	M	NW	26			W	16	NW	16°	SE	13	29
30	NW	22	SW	30	W	M	NW	33			SW	19	W	13	SW	16	30
31	NW	17			W	M	NW	19			SW	25			S	10	31
MONTHLY MAX	NW	26	N	31	SW	30	NW	33	W	27	SW	29	W	22	W	19	MAX
AVE		°°		17		16		20		17		°°		14		13	AVE

YEARLY MAX -- NW 33 MPH ON JAN 30

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1971-72

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	N	17	S	8	NW	25	SW	13	NW	22	W	18	W	18	1
2	M	M	W	20	W	7	W	34	N	19	W	20	W	21	NW	13	2
3	M	M	M	24	SW°	11	S°	21	W	28	NW	29	W	18	W	14	3
4	M	M	W	23	NE	7	N°	19	W	17	N	25	SW	16	W	11	4
5	NE°	8°	W	21	W	15	NW	30	W	15	W	30	W	19	SE	7	5
6	NE	11	NW	17	W	15	W	26	N	12	M	37	SW	23	F	14	6
7	NE	11	NE	10	S	13	SW	15	N	18	W	27	W	17	F	9	7
8	N	13	W	14	SW	12	SW	23	NW	13	NW	18	S	18	M	12	8
9	N	11	W	12	NW	15	NW	34	W	13	W	13	SW	20	M	11	9
10	NW	11	W	11	SW	15	W	33	S	7	W	17	S	27	S	11	10
11	W	12	W	9	SW	13	SW	46	NE	13	SW	15	S	29	S	11	11
12	NW	15	SW	11	SW	20	SW	35	NW	23	W	14	SW	26	NW	19	12
13	NW	15	W	17	SW	10	W	35	M	23	W	12	S	15	N	23	13
14	SW	14	SW	18	NE	13	W	26	W	20	N	14	SE	9	NW	12	14
15	SW	16	S	17	W	11	NW	20	W°	21	N	19	N	19	NW	10	15
16	S	21	S	12	N	20	W	14	M	28	W	22	S	16	S	9	16
17	S	23	S	6	N	10	N	18	NW	35	W	19	SW	21	S	14	17
18	N	15	S	10	NW	13	NW	22	W	18	SW	16	S	19	S	12	18
19	NE	10	NE	17	N	18	NW	17	M	17	SW	16	S	15	S	20	19
20	NE	8	NE	17	NW	27	NW	13	W	17	NW	18	NW	12	S	19	20
21	NE	7	NE	12	SW	16	SW	23	S	15	W	17	W	19	N	13	21
22	N	6	N	12	SW	21	SW	37	SW	24	S	10	W	21	NW	12	22
23	NE	7	NW	16	SW	29	SW	35	SW	22	S	12	NW	12	W	11	23
24	S	11	NW	14	SW	26	W	26	SW	25	W	16	M	11	W	8	24
25	S	16	SW	16	SW	31	SW	35	SW	16	SW	23	SW	16	SW	10	25
26	NW	17	M	16	SW	20	SW	27	M	21	S	22	NW	28	W°	M	26
27	SW	21	N	19	SW	14	SW	25	NW	23	SW	8	N	19	M	M	27
28	S	15	W	16	SW	16	W	23	SW	24	NW	13	NW	17	M	M	28
29	S	17	NW	11	W	15	M	12	SW	27	W	8	SW	15	M	M	29
30	W	20	NE	8	W	19	NE	10			NW	18	W	17	M	M	30
31	SW	14			NW	15	NE	9			NW	22			M	M	31
MONTHLY MAX	S	23	W	24	SW	31	SW	46	NW	35	W	37	S	29	N	23	MAX
AVE		14		15		16		25		20		18		18		13	AVE

YEARLY MAX -- SW 46 MPH ON JAN 11

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1972-73

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	W	5	N	19	NW	27	N	9	N	14	N	11	SE	11	SW	10*	1
2	SW	M	NE	10	W	22	N	10	NE	10	NE	9	NE	13	NW*	13	2
3	SW	9	N	8	W	19	SW	10	M	7	S	9	N	18	W	11	3
4	SE	12	W	M	SW	19	SW	9	NW	10	S	12	N	11	SW	15	4
5	E	6	W	M	NE	11	W	13	NW	9	N	12	N	11	F	11	5
6	E	5	N	12	SW	22	SW	16	SW	12	W	12	NW	15	NE	15	6
7	S	5	SW	14	SW	22	W	11	W	13	NE	10	S	14	N	15	7
8	NW	5	SW	14	SW	15	SW	15	SW	4	S	14	N	17	W	17	8
9	W	14	N	15	SW	8	NE	6	NE	M	S	9	NW	21	W*	17	9
10	SW*	20*	SW	8	SW	16	N	12	W	15	M	12	NW	14	W	18	10
11	E	10*	SW	7	SW	11	NE	11	SW	11	NW	13	NE	7	NW*	13	11
12	W	5	S	10	SW	15	W	19	N	19	SW	14	N	M	NW	11	12
13	W	10	NE	7	W	11	M	27	N	9	S	23	SW	11	SE*	9	13
14	S	8	SW	8	NW	13	N	16	W	9	N	18	SW	21	S	10	14
15	SW	M	N	12	M	17	M	9	NE	6	NE	15	SW	13	NW	14	15
16	W	16*	N	7	W	11	NE	10	NE	6	NW	17	NW	17	N	12	16
17	M	10	S	7	NW	11	W	13	N	M	W	12	SW	11	NW	14	17
18	SW	5	N*	M	N	19	M	17	N	10	SW	12	S	13	NW	15*	18
19	S	10	NE	6	NW	21	SW	20	NW	14	NE	7	NW	24	NW	M	19
20	SE	8*	S	15	NW	21	NE	11	W	14	S	7	NW	19	M	M	20
21	M	M	N	M	NW	17	NE	14	S	8	SW	18	NW	M	W	M	21
22	M	M	N	M	W	17	N	9	SE	14	NW	12	NW	15	NE*	11*	22
23	N	6*	S	6	N	19	NE	13	NE	11	SE	6	W	7	NW	16	23
24	S	11	N	20	W	19	N	M	NW	M	N	12	SW	6	NW	17	24
25	N	10	NW	22	NW	19	NE	4	NW	15	NE	9	NW	11	W	16	25
26	N	8	W	34	N	17	SE	8	W	10	N	M	NW	12	N	19	26
27	S	6	NW	16	SW	13	N	9	W	10	S	10	NW	15	N	28	27
28	W	10	NW	18	S	7	NW	17	W	6	S	9	W	19	N	17	28
29	SW	18	NW	24	N	14	W	19			S	9	SW	22	W	14	29
30	S	14	NW	31	N	22	SW	24			N	7	S	13*	S	9	30
31	S	8			NE	10	NE	8			N	14			SW	6	31
MONTHLY MAX	SW	20	W	34	NW	27	W	27	N	19	S	23	NW	24	N	28	MAX
AVE		09		13		16		13		10		12		14		14	AVE

YEARLY MAX -- W 34 MPH ON NOV 26

VAR - VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1973-74

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	NW	10	M	24	SW	18	M	9	W	16	SW	26	SW	23	W	19	1
2	SW	16	SW	20	SW	21	M	7	N	21	SW	40	NW	16	W	21	2
3	SW	12	SW	26	NE	12	M	12	N	21	W	15	N*	26	SW	16	3
4	E	7	W	20	N	18	SW	25	W	25	N	20	NW*	16	S	9	4
5	W	12	W	24	NW	20	S	21	NE	12	M	17	W	23	SW	8	5
6	W	15	W	23	N	20	W	21	NE	9	SW	25	SW	22	M	13	6
7	W	15	M	18	NW	22	M	19	N	14	SW	32	NW	19	NW	19	7
8	SW	14	NW	24	NW	20	SW	21	N	19	SW	21	W	14	NW	17	8
9	SW	9	W	15	W	23	SW	13	NW	18	SE	18	SW	23	M	17	M
10	VAR	7	W	14	NW	23	W	18	N	14	S*	14	N	15	SW	25	10
11	N	13	W	15	NW	20	W	18	NW	15	N	23	NW	27	SW*	21*	11
12	NW	21	W	24	W	26	W	16	M	18	W	9	NW	13	M	M	12
13	NE	18	SW	29	SW	16	NW	15	NW	9	W	20	N	19	SW*	22*	13
14	NE	9	M	22	NW	20	NW	20	N	11	SW	25	NW	16	SW	18	14
15	SW	11	NW	7	NW	24	NW	17	NW	19	W	21	NW	20	SW	33	15
16	NW	12	W*	15	NW	23	NE	10	SW	20	M	23	M	12	SW	21	16
17	NW	9	NW	13	W	16	W	9	NE	20	M	25	W	11	SW	15	17
18	N	11	SW	21	NE	13	N	11	NW	21	SW	15	SW	10	S	16	18
19	E	9	E	8	NE	10	W	17	SW	18	SW	17	SW	15	S	30	19
20	W	13	NE	12	NW	21	M	11	NE	21	W	15	NW	16	W	16	20
21	NW	10	M	12	N	17	SW	11	N	22	M	16	NW	13	M	18	21
22	W	11	SW	14	SW	20	M	18	SW	22	W	19	N	10	W	11	22
23	SW	31	SW	13	NE	17	N	11	NW	22	NW	18	S	12	SW	10	23
24	NW	19	N	13	N	20	N	9	N	15	M	17	SW	11	N	9	24
25	M	12	SW	13	N	22	W	15	NW	14	W	20	SW*	8*	NW	16	25
26	N	10	NE	9	NW	15	W	14	M	18	M	11	SW	23	NW	12	26
27	N*	18	NW	28	W	23	N	17	SW	31	W	18	SW	28	W	16	27
28	NE	14	NW	17	W	32	NW	19	M	23	M	26	S	10	SW	19	28
29	E	13	SW	26	W	27	NW	30			W	27	S	8	SW	19	29
30	NW	16	SW	18	N	17	NW	28			SW	25	N	9	W	14	30
31	W	21			NW*	13	W	18			NW	15			SW	12	31
MONTHLY MAX	SW	31	SW	29	W	32	NW	30	SW	31	SW	40	SW	28	SW	33	MAX
AVE		13		18		20		16		18		20		16		17	AVE

YEARLY MAX -- SW 40 MPH ON MAR 2

VAR - VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1974-75

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	W	12	W	8	NW	10	S	10	SW	19	W	18	S	16	NW	11	1
2	W	11	S	10	NW	10	N	19	NE	8	NW	12	NW	25	N	13	2
3	SW	11	S	7	NE	9	NW	15	NE	8	NW	16	SW	19	W	15	3
4	SW°	17	NE	11	NE	8	W	18	NE	5	SW	20	SW	27	SW	16	4
5	SW	15	SW	6	N	8	NW	21	N	14	SW	22	SW	20	SW	15	5
6	W	10	NE	11	N	18	SW	22	NW	21	SW	22	SW	29	NW	19	6
7	W	13	NE°	8	SE	9	W	21	W	20	W	15	NW	25	NW	17	7
8	NE	8	NE°	12	NE	9	SW	20	W	18	SW	13	NW	20	W	9	8
9	SW	9	N	11	NE	10	N	15	SW	21	N	12	NW	10	W	8	9
10	W	10	N	17	NE	7	NW	17	W	16	SW	11	S	14	W	11	10
11	S	8	NW	21	NW	19	NW	26	NW	23	SW	11	S	16	SW	12	11
12	S	9	NW	24	W	22	N	22	W	18	NE	7	SW	8	N	19	12
13	N	9	N	31	SW	20	W	22	SW	19	N	9	NE	13	N	20	13
14	N	13	NW	27	NW	22	W	25	SE	11	N	9	NW	15	N	12	14
15	N	13	NW	19	N	21	W	14	S	9	NE	8	M	20	W	10	15
16	NE	10	N	14	NW	26	W	18	NE	6	SW	13	W	28	W	11	16
17	S	6	NW	8	W	18	NW	23	S	14	N	16	W	15	NE	10	17
18	SW	7	NW	19	NW	18	NW	28	N	17	NW	17	N	21	NW	M	18
19	N	8	NW	18	W	23	NW	24	N	19	W	16	NW	16	W°	M	19
20	SW	6	NW	16	W	24	W	24	W	20	SW	25	N	10	S°	29°°	20
21	W	10	NE	9	W	23	E	12	NE	9	SW	19	SW	13	SW	29	21
22	S	12	NE	10	W	19	NE	14	N	14	SW	33	W	21	E	14	22
23	NW	6	N	18	SE	16	NW	19	N	18	NW	29	W	12	NW	16	23
24	NE	8	M	15	N	12	NW	37	NW	20	NW	28	SW	14	W	18	24
25	S	5	W	22	N	10	W	39	NW	14	S	17	SW	29	W	17	25
26	N°	6	NW	19	NE	7	SW	29	W	15	S	17	SW	29	W	11	26
27	M	7	NW	16	NE°	10°	SW	22	W	25	S	14	N	28	W	13	27
28	M	6	SW	10	M	M	W	21	W	23	N	13	N	24	E	14	28
29	S°	17	NE	10	S	10	SW	25			N	18	N	13	E	15	29
30	NW	13	N	13	N	9	SW	19			NW	19	NW	12	NE	12	30
31	NW	14			N	8	W	18			SW	16			NW	13	31
MONTHLY MAX	SW	17	N	31	NW	26	W	39	W	25	SW	33	SW	29	S	29	MAX
AVE		10		15		14		21		16		17		19		15	AVE

YEARLY MAX -- W 39 MPH ON JAN 25

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1975-76

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	SW	4	NW	22	NE	10	NW	21	SW	29	SW	15	NW	11	1
2	M	M	N	13	W	20	NE	14	NW	26	SW	20	SW	18	W	12	2
3	M	M	N	14	W	6	NW	15	S	19	SW	14	SW	11	S	9	3
4	M	M	NE	5	W	10	NW	19	SW	28	SW	12	SW	11	SW	13	4
5	M	M	NE	7	NW	11	W	16	SW	16	N	13	SE	15	S	14	5
6	M	M	W	14	N	17	N	14	W	9	NE	8	W	16	S	15	6
7	M	M	W	16	N	18	NW	17	W	20	SW	6	NW	14	S	7	7
8	M	M	NE	11	NW	23	W	14	W	21	NE	10	S	13	S	7	8
9	M	M	W	10	N	15	SW	23	SW	27	N	20	M	22	NW	13	9
10	M	M	SW	25	W	15	M	15	W	19	NW	14	M	16	S	9	10
11	M	M	NW	31	NW	8	W	17	NW	17	N	14	S	14	W	17	11
12	M	M	NW	18	SW	21	M	18	M	15	NE	11	S	20	NW	23	12
13	M	M	NE	11	SW	12	M	17	NW	16	N	18	S	18	NW	20	13
14	M	M	NW	10	SW	12	W	20	W	17	W	16	S	16	NW	14	14
15	M	M	N	10	NW	25	M	28	M	9	N	22	N	11	S	10	15
16	NW	19	W	13	W	24	NW	21	NW	17	NW	21	NW	13	S	6	16
17	NE	11	SW	16	NW	20	NW	16	NW	23	NW	17	N	12	NW	12	17
18	NE	9	S	11	N	7	W	12	M	24	NW	24	SW	7	M	9	18
19	N	9	NE	11	NE	9	NE	8	SW	18	W	27	N	12	S	11	19
20	W	11	NE	11	NE	5	N	13	N	18	N	25	NW	19	S	8	20
21	W	13	N	7	NE	8	NW	10	N	14	NW	27	W	20	NE°	M	21
22	M	13	NE	10	NE	8	NW	17	NW	17	NW	20	SW	17	NW	11°	22
23	S	7	NW	19	NE	7	NW	14	SW	15	W	30	W	16	NW	16	23
24	M	9	NW	20	NE	13	NW	11	SW	18	W	21	NW	18	W	11	24
25	NW	10	N	21	N	12	NW	14	W	16	W	24	S	15	W	12	25
26	W	23	NW	19	N	18	NW	22	W	13	N	17	S	22	N	9	26
27	SW	21	SW	13	N	30	NE	13	SW	10	W	21	S	11	W	6	27
28	W	14	SW	18	NE	12	N	14	SW	17	E	11	SW	9	SW	12	28
29	W	11	SW	13	NE	11	NW	14	SW°	21	E	9	SW	10	SW	8	29
30	SW	10	W	34	SW	12	W	25			N	16	N	15	VAR	9	30
31	SE	8			S	10	N	18			NE	13			N	9	31
MONTHLY MAX	W	23	W	34	N	30	W	28	SW	28	W	30	M	22	NW	23	MAX
AVE		°°		15		14		16		18		18		15		11	AVE

YEARLY MAX -- W 34 MPH ON NOV 30

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1963-64

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	340	16	12	290	21	19*	250	21	04	250	25	23	220	23	18	220	33	24	220	19	02	200	23	22*	1
2	220	17	24*	360	17	23*	340	15	05*	220	34	07	040	18	12	220	29	01	310	22	06	200	34	12	2
3	220	19	01*	360	12	05*	360	12	02	310	22	05	090	17	24	310	21	17*	360	18	03	200	38	17	3
4	040	12	13*	290	26	17	310	14	04*	250	24	10	090	24	01	290	34	20	130	20	04	220	38	06	4
5	250	14	21*	220	25	03	340	12	22	270	26	24	340	25	12	290	26	01	290	29	11	200	40	11	5
6	310	10	05*	220	27	24	340	31	23	290	27	02	M	M		270	15	11*	200	16	19*	220	19	15	6
7	180	11	24*	220	29	02	290	34	16	290	19	01	M	M		180	12	06	360	14	16*	200	30	11	7
8	220	17	01*	290	27	16*	290	22	01	290	20	24*	290	33	03	360	17	22*	270	16	18*	340	19	05	8
9	270	10	02	290	26	09	220	23	05	290	32	11	290	32	22	360	20	05	340	14	01	M	M		9
10	040	18	10*	290	17	24*	160	22	12	200	22	08	290	35	01	290	23	19	310	28	21	M	M		10
11	200	20	21	310	22	04*	290	15	16	340	25	18	270	26	12	270	29	14	220	32	24	M	M		11
12	180	20	19	290	21	16*	270	34	18	310	18	01	180	20	07	200	42	11	290	34	15	M	M		12
13	220	20	02	M	M		270	32	09	290	18	04	360	12	22*	310	19	24	290	43	21	M	M		13
14	340	13	02*	290	20	09*	270	26	01	220	14	19*	340	21	16*	290	32	13*	290	37	02	M	M		14
15	040	10	14*	220	30	24*	270	27	15	340	18	15*	220	23	23	250	23	03	200	30	24	M	M		15
16	200	12	19*	220	27	08*	250	19	15	220	31	19	270	21	11	340	17	17	220	42	06	M	M		16
17	340	14	12*	M	M		250	36	12	220	36	23	270	29	13*	360	18	05*	200	24	13	M	M		17
18	310	10	03*	M	M		360	23	01*	220	35	08	M	M		360	21	23	200	28	05	M	M		18
19	160	14	09*	M	M		290	23	17	M	M		290	26	01	340	29	16	180	28	13	M	M		19
20	M	M		200	21	10*	290	23	01*	M	M		270	18	20	340	20	10	290	27	24	M	M		20
21	M	M		M	M		110	15	13*	M	M		310	23	13	200	40	24	290	32	03	M	M		21
22	360	16	04*	M	M		340	21	15	220	26	04	310	27	24	200	35	07	220	32	04	M	M		22
23	290	19	12	M	M		340	24	06	270	26	14	310	22	01	M	M		160	28	20	M	M		23
24	250	14	14	M	M		340	20	02	290	29	17	310	17	02	M	M		180	26	11	M	M		24
25	250	12	16*	M	M		290	21	10	270	27	05	270	21	13	290	33	14	200	25	02	M	M		25
26	220	17	11	M	M		290	21	22	250	22	03	340	26	22	290	26	16	310	41	24	M	M		26
27	290	16	09*	M	M		310	30	15*	270	20	10	310	25	19	290	28	06	340	41	01	M	M		27
28	230	14	08*	270	23	21	290	26	03	270	19	16	360	17	02	290	27	12	310	27	05	M	M		28
29	220	14	15*	250	23	01	340	33	03	310	11	23	270	23	23	290	22	12	110	19	17	M	M		29
30	200	29	16*	290	20	01	310	23	08	310	19	17				310	20	12	180	13	15*	M	M		30
31	020	12	01*				310	22	19	290	28	13				220	19	24				M	M		31
MONTHLY MAX	200	29	16	220	30	24	250	36	12	220	36	23	290	35	01	200	42	11	290	43	21	200	40	11	MAX
AVE		15			23			23			24			23			25			27			30		AVE

YEARLY MAX -- 43 MPH ON APR 13 AT 2100 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1964-65

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		290	20	01	290	14	22*	290	30	12	180	15	18*	160	26	14*	200	35	23	1
2	M	M		M	M		340	19	04	220	16	21*	290	30	24	M	M		200	37	01	210	33	03	2
3	M	M		360	20	01*	340	9	05	220	29	05	290	48	02	340	33	20	250	15	10*	M	M		3
4	M	M		M	M		340	10	14*	270	19	12*	290	24	12	360	21	06	160	20	09	M	M		4
5	M	M		M	M		310	12	03*	220	30	13	250	22	14	360	13	09*	270	23	22*	M	M		5
6	M	M		310	18	15	360	13	18*	220	31	07	220	19	05*	040	9	12*	250	25	04*	M	M		6
7	M	M		310	15	09	M	M		220	38	09	180	21	07*	220	15	22*	200	27	03	M	M		7
8	M	M		250	22	14	310	16	18*	M	M		290	14	19*	270	17	20*	200	29	24	M	M		8
9	M	M		220	32	21	340	19	24*	310	18	24*	130	19	24*	290	23	06*	200	37	09	M	M		9
10	M	M		250	33	08*	310	20	04	250	25	22*	110	26	16	220	28	02	250	24	06*	M	M		10
11	M	M		340	31	16*	220	28	22*	270	12	02*	180	23	01	180	16	24*	360	21	11	M	M		11
12	M	M		250	24	15	270	30	17	290	27	17	290	31	08	180	17	01*	110	39	18	M	M		12
13	M	M		220	27	14	290	48	14	290	37	09	310	27	03	270	23	11*	200	39	09	M	M		13
14	M	M		110	30	18	220	31	24	290	38	21	310	26	05	270	26	07	360	23	18	M	M		14
15	M	M		180	23	02	220	42	08	310	35	02	200	18	01*	250	23	08*	340	23	05	M	M		15
16	M	M		220	24	20	250	38	02	360	16	01*	340	21	15	270	30	16*	220	31	19	M	M		16
17	M	M		200	22	02*	290	27	13	340	16	05*	360	16	06*	290	33	04	220	38	01	M	M		17
18	M	M		020	15	24*	220	24	06*	020	11	10	310	13	19	290	26	04	200	33	01	M	M		18
19	M	M		340	34	07*	310	27	07*	160	17	22	290	13	24	340	23	18	290	32	12	M	M		19
20	M	M		M	M		200	47	21	200	19	04	270	32	17	290	33	14	250	34	02	M	M		20
21	M	M		M	M		250	26	11	340	13	08*	290	31	12	220	37	23	220	22	18	M	M		21
22	M	M		M	M		200	43	21	340	25	07	200	35	02	220	31	02	200	24	05*	M	M		22
23	M	M		M	M		220	43	10	340	30	06	290	26	22*	250	26	08*	200	33	16*	M	M		23
24	M	M		270	33	16	290	41	02	200	37	09	290	37	06	250	20	01	340	16	18	M	M		24
25	360	12	05*	290	30	14	290	33	05	340	29	17*	270	31	06	250	25	23*	110	24	19*	M	M		25
26	M	M		220	40	22	22	22	23	290	35	18	290	22	15*	200	35	08	040	20	23	M	M		26
27	M	M		220	28	01	250	29	15*	200	38	24	270	24	14	200	32	20	090	16	11*	M	M		27
28	360	19	09	240	30	17	200	28	08*	250	35	04	310	22	07*	220	27	01*	M	M		M	M		28
29	270	15	07	300	30	16	270	23	14*	290	44	21				270	15	19*	270	15	23*	M	M		29
30	240	31	03*	290	25	02	200	24	22	290	38	02				220	18	22*	270	20	09*	M	M		30
31	320	18	11*				200	24	12	220	37	11				270	19	10				M	M		31
MONTHLY MAX	240	31	03	220	40	22	29	48	14	290	44	21	290	48	02	220	37	23	110	39	18	200	35	23	MAX
AVE		19			27			27			27			25			24			26			34		AVE

YEARLY MAX -- 48 MPH ON DEC 13 AT 1400 HOURS

G INDICATES GUSTINESS. DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1965-66

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		360	13	04*	340	12	20*	310	17	24	310	21	03*	220	36	07	310	26	14	320	15	05*	1
2	M	M		360	14	16	310	22	14	M	M		M	M		270	26	18	310	31	09	M	M		2
3	M	M		340	15	01	270	37	04	250	20	09*	310	26	20*	340	33	16	020	16	04	180	18	19*	3
4	M	M		360	15	12*	310	25	20	250	22	01	310	20	03	340	35	04	360	23	21	180	17	01*	4
5	M	M		020	15	01*	310	16	13	290	18	04	270	21	03*	310	28	01	310	33	15	M	M		5
6	M	M		020	11	14*	250	15	21	290	33	16	220	14	14*	340	22	03	310	30	14	M	M		6
7	M	M		020	11	08*	250	15	05	290	34	10	220	22	02*	310	25	13	310	32	11*	M	M		7
8	M	M		200	14	06	290	12	03	250	38	15	130	23	04*	310	24	11	310	19	24	M	M		8
9	M	M		290	18	12	200	14	24*	290	37	12	290	14	02*	310	23	04	310	27	02	M	M		9
10	M	M		250	14	12	160	23	04	290	26	13	250	14	24*	310	20	10	180	16	16*	M	M		10
11	M	M		250	25	15	340	30	15	250	25	09	020	22	14	310	18	19	360	21	24*	M	M		11
12	M	M		250	19	08	310	19	05	340	25	01*	310	23	02*	310	14	03	340	20	05*	M	M		12
13	M	M		M	M		200	12	04*	020	16	15	290	25	22	310	18	24	M	M		M	M		13
14	M	M		250	33	11	200	13	03*	340	22	21	290	26	01	310	18	01	M	M		M	M		14
15	M	M		250	30	22	200	15	11*	340	21	02	340	25	24*	180	32	24	310	19	17*	M	M		15
16	110	19	15	290	17	04	310	14	20*	290	14	22*	290	29	02	180	51	16	310	19	12*	220	20	02	16
17	110	19	22	250	31	15	270	11	05*	020	15	02*	290	34	18	340	35	21	180	24	23*	220	21	11	17
18	070	28	07	290	21	05	340	20	21*	200	13	19*	290	28	01	310	27	15	180	30	13*	320	23	16	18
19	290	23	20	340	22	12	290	31	24	020	14	15*	220	23	23	VAR	33	18	180	16	02*	320	22	10	19
20	340	26	01	220	22	09	290	28	01*	200	13	11*	340	24	13	180	27	17	310	26	12*	320	24	09	20
21	360	16	15	220	25	17	290	24	10	290	23	19*	020	15	15*	180	36	14	180	20	14	220	29	18	21
22	340	16	21	270	15	08	220	32	20	290	18	12	020	13	17*	340	28	13*	180	14	02*	220	36	20	22
23	270	14	24	220	37	14	200	29	01*	250	13	08	020	12	20	340	22	09	310	15	12*	320	18	16*	23
24	310	20	20	220	27	19	250	30	24*	290	24	22	200	16	23	340	16	12*	310	11	03*	220	14	22*	24
25	360	13	14	220	31	03	200	46	15	290	31	08	200	20	02	310	19	04	310	13	03*	360	20	17*	25
26	270	14	05	M	M		250	31	05*	290	22	16	020	13	15	340	18	06*	180	30	20	M	M		26
27	290	11	07	340	30	21*	250	25	18	250	14	10	310	27	16	340	18	03*	310	31	08	M	M		27
28	270	13	05	340	24	10	250	46	22	290	26	21	220	24	22	340	17	18	180	29	09*	180	14	15*	28
29	360	16	13	270	21	14	250	51	08	290	25	06				020	25	12	180	24	02*	220	13	01*	29
30	360	17	13*	020	11	23*	220	41	11	250	23	06*				340	20	16	310	17	15	220	28	21*	30
31	200	15	03				250	25	03	340	21	21*				340	25	17				360	19	10*	31
MONTHLY MAX	070	28	07	220	37	14	250	51	08	250	38	15	290	34	18	180	51	16	310	33	15	220	36	20	MAX
AVE		18			21			25			22			22			26			23			21		AVE

YEARLY MAX -- 51 MPH ON DEC 29 AT 0800 HOURS

G INDICATES GUSTINESS. DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1966-67

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		260	22	21	300	21	03	350	12	12	220	35	22*	220	31	13	020	36	04	1
2	M	M		M	M		M	M		300	23	23	290	19	19	230	31	04	240	23	14	260	12	10	2
3	M	M		M	M		260	35	09	290	23	12	310	24	23	220	28	19	240	25	07	280	17	13	3
4	M	M		M	M		300	12	08	290	21	14	270	36	20	230	21	11	240	32	04	260	18	11	4
5	M	M		M	M		250	44	10	220	27	13	290	41G	01	300	14	20	230	30	10	230	25	11	5
6	M	M		M	M		250	35	20	300	37	15	280	25	15	270	24	12	290	15	03	330	30	15	6
7	M	M		M	M		260	27	04	330	23	01*	330	25	04	270	27	16	230	20	09	320	42	07	7
8	M	M		M	M		290	20	20	020	14	12	280	19	20	260	28	12	250	27	13	320	35	09	8
9	M	M		M	M		290	19	06	320	15	04	270	40	05	260	27	04	M	M		230	31	24	9
10	M	M		M	M		300	22	10	020	12	14	280	40	10	240	31	09	200	31	24*	230	40	01	10
11	M	M		M	M		010	10	02	290	30	13	280	26	13	240	31	08	200	30	01	230	17	16	11
12	M	M		M	M		300	17	21	300	21	11	240	22	19	240	32	15	180	29	14	240	23	03	12
13	M	M		M	M		290	23	01	290	25	24	220	31	24	240	30	15	330	42	13	260	25	10	13
14	M	M		M	M		300	20	16	290	36G	06	200	35	09	230	25	02	280	31	04	020	25	20	14
15	M	M		M	M		320	11	08	270	30	23	290	30	05	240	16	02	210	35	08	320	34	10	15
16	M	M		M	M		280	14	22*	270	26	02	280	27	21	250	16	12	200	29	03	360	20	06	16
17	M	M		M	M		310	9	02	M	M		290	40	20	250	16	08	200	18	24	320	20	09	17
18	M	M		M	M		360	16	13	M	M		260	40G	02	240	21	11	180	19	12	030	29	16	18
19	M	M		M	M		290	16	24	M	M		030	17	16	240	26	15	200	34	14	270	20	14	19
20	M	M		M	M		290	19	02	M	M		350	20	05	250	18	12	230	26	07	020	15	15	20
21	M	M		M	M		230	17	18	M	M		290	32	11	250	18	12	270	21	06	360	14	06	21
22	M	M		M	M		340	16	18	M	M		290	30	05	250	15	02	250	17	02	010	17	10	22
23	M	M	260	15	14*	010	9	01	M	M		270	25	12	250	17	24	250	19	24	220	17	17	23
24	M	M	250	32	24	290	19	06	M	M		320	21	14	M	M		250	20	05	260	23	24	24
25	M	M	250	37	01	040	9	12	M	M		210	25	16	M	M		320	21	14	M	M		25
26	M	M	270	27	10	150	11	11	M	M		210	22	02	220	25	16	240	16	24	M	M		26
27	M	M	280	24	22	210	24	24	M	M		340	15	12	240	15	24	260	28	05	M	M		27
28	M	M	280	17	12	210	20	01	M	M		300	17	04	240	45	22	250	35	02	M	M		28
29	M	M	270	30	05	280	18	08	M	M					220	46	16	250	50	03	M	M		29
30	M	M	280	16	07	290	16	20	M	M					240	27	20	320	30	16	M	M		30
31	M	M				290	26	06	190	11	01				240	31	02				M	M		31
MONTHLY MAX			250	37	01	250	44	10	300	37	15	290	41G	01	220	46	16	250	50	03	320	42	07	MAX
AVE				25			19			23			27			25			27			24		AVE

YEARLY MAX -- 50 MPH ON APR 29 AT 0300 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1967-68

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		M	M		M	M		290	35	11	020	13	01	220	13	12	290	16	06	1
2	M	M		M	M		M	M		M	M		300	22	16	230	10	18	160	20	10	330	16	19*	2
3	M	M		M	M		M	M		290	39	13	340	21	13	030	11	11	350	26	06	340	20	17	3
4	M	M		M	M		M	M		340	23	02	340	9	01	020	15	12	020	15	10*	210	20	24	4
5	M	M		M	M		M	M		250	25	22	330	10	19	360	8	04	220	30	22	240	20	07	5
6	M	M		M	M		M	M		300	25	05	300	15	22	350	11	08	220	27	01	330	31	23	6
7	M	M		M	M		M	M		260	20	22	210	14	24	280	25	23	270	22	09	280	35	06	7
8	M	M		M	M		M	M		260	26	02*	220	14	01	270	22	01	300	20	24	290	21	06	8
9	M	M	270	15	24	340	17	13	M	M		020	9	11	190	10	02	300	25	01	210	23	03	9
10	M	M	270	20	09	280	21	20	M	M		220	11	20	200	16	21	280	14	17	020	15	15	10
11	M	M	270	20	01	270	32	04	250	24	01	290	18	08	200	16	07	280	15	04	220	20	24	11
12	M	M	250	15	07	250	28	23	290	16	08	190	23	12	340	20	08	210	22	24	240	13	01	12
13	M	M	270	15	14	240	31	12	320	22	08	230	17	08	230	40	16	240	31	06	280	24	15	13
14	M	M	270	20	11	260	21	10	330	20	04	340	16	19	240	20	01	250	30	06	220	34G	15	14
15	M	M	270	20	02	260	38	24	020	9	04	300	16	12	280	23	04	240	31	23	290	25	06	15
16	M	M	270	24	11	250	35	02	240	11	18	300	26	07	230	31	24	210	24	17	210	19	02	16
17	M	M	340	14	10	270	20	06	300	15	01	290	22	24	210	30	04	190	15	14	290	18	09	17
18	M	M	260	16	02	260	30	17	030	14	10	320	27	14	240	33	02	170	22	13	330	20	08	18
19	M	M	250	21	11	240	20	14	010	11	10	300	31	14	290	12	02	290	24	19	280	14	11	19
20	M	M	270	26	12	270	27	14*	020	10	02	290	26	02	020	9	15	200	24	24	220	17	22	20
21	M	M		M	M		300	28	13	010	7	03	290	25	06	320	35	20	200	24	01	M	M		21
22	M	M		M	M		290	33	03	020	17	08	330	26	11	320	37	06	140	14	03*	M	M		22
23	M	M		M	M		300	25	14	350	15	08	290	26	21	280	16	24	340	19	10	M	M		23
24	M	M		M	M		300	32	05	290	14	24	310	27	19	280	22	11	300	16	01	M	M		24
25	M	M		M	M		300	25	12	220	22	24	300	18	15	290	17	01	280	17	10	M	M		25
26	M	M		M	M		300	33	14	220	26	01	290	18	02	220	38G	03	300	15	24	M	M		26
27	M	M		M	M		300	25	15	220	30G	10	260	14	02	250	19	02	090	11	13	M	M		27
28	M	M		M	M		340	22	06	220	30	15	340	26	18	350	19	14	320	12	17	M	M		28
29	M	M		M	M		350	12	06	230	25	22	340	24	01	290	16	03	310	9	01	M	M		29
30	M	M		M	M		320	13	24	230	32	02				330	20	21	290	15	09	M	M		30
31	M	M					300	33	07	240	21	02				280	12	10				M	M		31
MONTHLY MAX			270	26	12	260	38	24	290	39	13	290	35	11	230	40	16	240	31	06	280	35	06	MAX
AVE				19			26			20			20			20			20			21		AVE

YEARLY MAX -- 40 MPH ON MAR 13 AT 1600 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1968-69

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		190	10	11	290	21	05	290	30	05	260	25G	04	210	26	05	340	19	15*	230	17	01	1
2	M	M		350	14	10	300	28	19	330	24	20	290	40G	12	040	15	02	220	17	24	190	16	12*	2
3	M	M		220	21	23	290	38G	18	340	15	03	300	18	07	190	13	22	220	29	03	210	18	12	3
4	M	M		230	25	16	300	45G	10	320	21	07	240	17	22	180	20	16	340	26	04	150	14	19	4
5	M	M		350	14	06	240	30G	06	290	34G	09	290	20	21	360	16	16	190	12	24	110	12	18	5
6	M	M		330	14	19	250	19	03	290	40G	07	240	20	03	290	19	02	180	40G	22	080	24	12*	6
7	M	M		290	20	07	250	25	22	240	45G	24	330	22	17	140	24	09	280	35G	10	M	M		7
8	M	M		290	23	10	240	26	14	230	55G	01*	330	15	01	280	14	17	340	23	05	M	M		8
9	260	16	20*	290	42G	18	260	16	24	230	26	24	260	15	03	260	18	07	290	16	04	M	M		9
10	260	15	12	350	37	09	230	25	20	220	31	01	290	22	23	180	14	11	030	12	15	M	M		10
11	360	13	01*	280	26	09	230	49G	06	240	22G	16	340	27	12	290	24	24	130	15	12	M	M		11
12	230	15	03	240	40G	16	300	40G	18	300	20	03	270	13	09	300	21	01	040	12	17	M	M		12
13	230	17	19	230	20	05	320	30	02	240	18	24	210	22	02	290	15	01	240	10	22	M	M		13
14	220	32	22	230	14	22	240	17	18	260	15	11	280	18	20	190	11	09	130	19	24	280	16	15*	14
15	220	26	01	250	25G	24	230	26	15	240	22	14	300	19	03	360	12	15	150	26	08	330	19	21	15
16	360	24	20	220	37G	02	220	24	15	220	24	05	350	11	24	010	11	16	190	14	01	350	14	16	16
17	010	20	07	300	28	08	230	27	01	250	22G	19	350	17	10	230	17	22	340	22	17	290	18	14*	17
18	290	16	14	290	32	06	300	26	15	240	20	24	170	17	19	280	25	10	220	16	13	250	20	10	18
19	270	19	04	330	20	07	310	20	04	250	25G	07	170	19	01	280	32	11	270	20	20	250	19	12	19
20	250	17	14	310	23	02	160	15	15	250	25G	17	030	19	03	320	16	03	290	29	11	220	19	15	20
21	250	30G	07	330	13	01	340	23	22	220	19	19	220	16	24	280	19	10	290	16	03	220	15	16	21
22	290	31	24	290	32	16	330	34	04	230	30	19	210	32	04	200	22	03	200	35	19	280	16	11	22
23	340	41	15	290	25	12	250	29	02	220	29	01	200	22	23	240	21	04	200	16	02	320	22	15	23
24	340	22	01	220	37	23	240	30G	23	210	20	11	210	35	19	350	17	06	200	25	20	300	11	16	24
25	310	11	05	230	20	05	230	56G	04	220	31	21	220	35	10	300	27	24	340	29	07	250	10	01	25
26	290	30	13	360	10	02	220	24	01	210	45G	19	210	39	02	320	26	08	350	23	17	260	13	05	26
27	330	31	16	040	15	12	290	25G	14	230	32	10	280	21	12	280	35	16	330	32	06	220	12	11	27
28	330	20	01	040	9	17	240	30G	19	210	25	11	210	21	02	280	25	01	300	16	04	150	13	22*	28
29	240	16	23	040	17	12	300	27	04	220	28	01				290	30	11	220	20	24	230	11	12	29
30	220	25	09	020	16	08	290	36	22	220	35G	14				220	21	20	220	25	11	280	19	20	30
31	260	17	17				280	40G	04	270	37G	12				M	M					290	14	17	31
MONTHLY MAX	340	41	15	290	42G	18	230	56G	04	230	55G	01	290	40G	12	280	35	16	180	40G	22	080	24	12	MAX
AVE		22			23			29			28			22			20			22			16		AVE

YEARLY MAX -- 56G MPH ON DEC 25 AT 0400 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1969-70

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		070	8	15	010	18	15	340	35G	10	210	25	22	300	26	21	030	15	13	1
2	M	M		M	M		020	13	20	350	25	13	320	32G	17	210	33	08	240	21	14	330	19	04	2
3	M	M		M	M		010	15	02	290	39G	11	290	35G	07	240	17	14	340	16	18	020	14	09	3
4	M	M		300	19	12	300	24	15	220	33G	01	230	29G	09	290	15	04	290	20	17	220	11	05	4
5	M	M		020	11	19	360	13	24	350	20	20	280	25	23	260	12	01	300	28	11	210	11	22	5
6	M	M		020	13	07	310	20	16	280	23	24	290	27G	06	330	22	17	210	19	22	220	16	13	6
7	M	M		230	26G	23	290	20	18	280	36	11	350	21	05	290	23	15	240	18	14	250	25	24	7
8	M	M		280	16	01	280	27	14	280	30	01	340	24	13	240	21	24	290	25	12	280	25	13	8
9	M	M		200	16	02	050	11	03	290	26G	19	310	20	02*	240	25	01	010	11	02	310	24	03	9
10	M	M		240	22G	02	290	28G	14	260	42G	05	290	19	09	220	16	02	260	25	18	220	36	24	10
11	M	M		300	24	14*	270	27	04	300	25	05	310	17	24	040	12	13	220	28	05	230	43G	02	11
12	M	M		M	M		270	23	01	280	30	24	300	20	01	290	22	24	290	21	06	240	27G	10	12
13	M	M		290	36	06	280	26	02	270	26	10	240	23	08	290	24	01	180	16	23	210	29G	13	13
14	M	M		340	38	03	290	17	17	310	22	04	300	14	09	290	23	16	190	40G	12	340	16	07	14
15	M	M		290	21	05	270	11	06	340	20	16	320	21	04	250	11	01	240	23	12	340	21	10	15
16	M	M		230	28	07	210	24	19	200	20	18	290	30	03	300	17	15	140	24	23	330	22	09	16
17	M	M		350	28	16	240	16	02	300	28G	08	240	35G	13	210	22	11	180	32	11	290	25	10	17
18	M	M		340	26	18	270	15	01	280	29G	12	290	25	04	340	23	06	290	23	08	220	17	05	18
19	M	M		300	28G	20	230	16	18	230	36G	10	020	14	15	300	14	18	300	21	01	210	20	10	19
20	M	M		320	30	06	310	38G	11	320	30G	15*	200	14	19	050	11	13	230	30	24	220	22	24	20
21	M	M		220	16	06	210	28	19	280	32	05	210	17	02	300	17	16	250	27	01	230	20	04	21
22	M	M		050	15	14	220	37G	03	290	42G	18	160	20	20	300	25	07	240	23	13	220	16	10	22
23	M	M		300	15	23	210	28	17	300	34G	03	210	13	01	300	35	15	290	17	14	270	13	09	23
24	M	M		280	20	13	340	35G	18	220	44G	13	200	11	21	300	35G	09	290	23	08	250	16	15	24
25	M	M		260	19	23	210	23	23	210	35G	22	300	18	24	350	35	10*	300	27	03	M	M		25
26	M	M		290	23	02	220	33G	08	220	38G	24	300	21	01	300	24	04	230	32	22	M	M		26
27	M	M		030	12	03	170	10	06	220	34G	01	260	12	18	200	16	07	210	29	21	M	M		27
28	M	M		020	10	01	190	17	20	280	34G	13	210	22	24	030	14	03	230	29	10	M	M		28
29	M	M		020	12	18	030	19	21	290	34G	11				140	20	24	020	14	17	M	M		29
30	M	M		030	14	08	340	28	17	290	21	01				130	28	03	030	17	10	M	M		30
31	M	M					340	23	12	280	26	24				200	15	18				M	M		31
MONTHLY MAX				340	38	03	310	38G	11	220	44G	13	340	35G	10	300	35	15	190	40G	12	230	43G	02	MAX
AVE					21			22			30			22			21			24			21		AVE

YEARLY MAX -- 44G MPH ON JAN 24 AT 1300 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1970-71

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		350	26	08	220	33G	03	230	19	03	290	15	01	M	M		290	30	02	270	22	09	1
2	M	M		010	21	17	220	47G	15	200	27	20	210	24	24	M	M		290	29	12	260	16	10	2
3	M	M		350	22	03	210	35G	21	180	23	02	220	32	04	M	M		280	26	05	190	16	14	3
4	M	M		220	9	07	220	35G	02	300	19	18	290	31G	24	M	M		340	18	15	160	21	14	4
5	M	M		300	24	10	290	25	02	300	17	07*	280	30G	01	M	M		340	21	08	270	23	06	5
6	M	M		240	22	24	280	16	24*	M	M		290	31	15	M	M		230	20	24*	170	15	09	6
7	M	M		230	26	03	270	20	03	M	M		290	35	21	M	M		220	27	19	150	11	02	7
8	M	M		350	44	07	230	29G	12*	290	25	17*	330	36	23	M	M		290	24	02*	180	35	17	8
9	M	M		310	26	05	M	M		300	30	03	340	30	01*	M	M		M	M		310	27	23	9
10	M	M		250	25	11	350	22	17*	240	43G	12	280	46G	16	M	M		M	M		330	28	06	10
11	M	M		290	29	21	230	26G	21	220	40	23	290	39G	04	M	M		220	25	16*	150	14	18	11
12	M	M		260	19	03	M	M		220	40	03*	280	29	07	290	30	10	M	M		360	15	09	12
13	M	M		350	24	22	M	M		240	35G	06	280	30	16	240	34G	07*	M	M		350	16	10	13
14	M	M		350	29	02	M	M		230	29G	06	300	21	03	M	M		M	M		250	14	22	14
15	M	M		280	16	20	M	M		250	31	24	250	22G	16	M	M		M	M		210	20	15	15
16	M	M		290	22	02	M	M		300	24	05	250	25G	11	M	M		M	M		180	36	22	16
17	M	M		300	25	10	M	M		290	27	24	220	25	12	210	30	02	160	24	14	330	20	21	17
18	M	M		240	17	09	230	24G	16	290	25	01	340	25	19	350	28	24	150	28	14	010	15	01	18
19	M	M		290	39	10	220	25	23	300	30	02	130	26	23	300	30	03	090	34	12	270	27	08	19
20	M	M		220	41G	23	220	18	08	240	35G	14	130	30	05	310	27	15	290	28	24	190	20	15	20
21	M	M		220	46G	16	230	22G	11	230	35G	22	190	21	02	270	22	04	290	27	01*	190	20	24	21
22	350	17	24	240	28G	05	280	33G	15	240	35G	06	010	15	01*	290	22	17	020	10	16	160	30	13	22
23	360	19	01	280	35	12	350	30	03	290	30	19	020	16	15	240	26	20	160	15	17	340	34	15	23
24	230	34	11	220	32G	22	280	30	22	290	35	22	300	28	03	290	31	13	M	M		310	27	10	24
25	240	31	06	220	45G	12	290	27	02	260	30G	09	230	42	11	240	25	22	M	M		210	16	16	25
26	310	14	03	210	36	01	210	19	21	290	30	04	290	46G	05*	220	41	22	M	M		150	17	23	26
27	300	25	21	230	25G	02	270	24G	07	290	30	11	M	M		230	35	04	M	M		170	21	16	27
28	290	29	11	220	28G	23	M	M		290	34	20	M	M		230	25	01	220	17	04*	160	26	15	28
29	300	38G	10	220	46G	24	M	M		290	37	24				290	21	01	310	21	19*	VAR	23	19	29
30	300	32	10	230	44G	11	M	M		290	49G	16				220	34	22	300	19	01	220	31	16	30
31	290	22	12				M	M		320	29	01				230	30	03				200	16	16	31
MONTHLY MAX	300	38G	10	220	46G	16	220	47G	15	290	49G	16	280	46G	16	220	41	22	090	34	12	180	36	22	MAX
AVE		26			29			27			31			29			29			23			22		AVE

YEARLY MAX -- 49G MPH ON JAN 30 AT 1600 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1971-72

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		240	30	18	180	13	14	250	40	21	210	21	08	350	34	05	270	25	15	270	33	14	1
2	M	M		230	30	01	300	11	14	300	58G	02	290	27	16	240	37	24	270	31	03	300	20	02	2
3	M	M		290	30	11	200	24	09*	170	33	09*	290	41	15	290	44	13	280	25	07	280	23	08	3
4	M	M		290	29	13	290	11	24	300	36	23*	310	25	01	280	40	05	220	25	06	280	22	11	4
5	040	15	22*	250	29	05	290	35	18	300	39	17	290	26	12	290	40	22	200	44	22	230	14	02	5
6	050	15	01	300	27	04	230	31	10	290	36	15	360	15	04	240	55G	18	200	34	08	130	16	06	6
7	140	15	18	300	19	05	160	23	12	240	30	21	340	27	06	250	41	02	280	26	11	100	25	02	7
8	360	20	16	310	20	20	280	24	24	230	32	07	310	21	05	300	26	06	200	34	22	M	M		8
9	020	14	05	300	18	20	300	30	04	290	50G	12	240	22	02	280	20	05	200	32	04	M	M		9
10	350	17	13	280	17	12	280	22	05	250	44G	08	180	10	01	210	24	23	190	40	20	190	24	10	10
11	310	21	23	240	16	14	360	18	18	230	66G	13	310	19	24	230	30	04	190	41	03	340	20	24	11
12	330	23	04	210	17	21	210	34	18	240	44G	01	280	35	05	290	24	11	200	35	24	340	25	03	12
13	300	23	15	290	26	11	230	26	01	290	49G	06	240	39	20	280	20	12	200	35	01	340	37	03	13
14	220	25	23	220	27	08	210	24	02	290	40G	07	230	30	01	320	21	18	160	14	03	330	15	02	14
15	220	22	09	200	25	05	240	15	07	290	30	01	290	35	10*	340	25	12	360	24	10	300	15	06	15
16	180	35	22	190	21	13	340	29	08	250	20	22	M	M		250	35	16	210	39	24	200	18	24	16
17	210	35	08	360	11	02	350	27	04	290	36	23	290	45	16	240	26	14	210	49	02	200	21	03	17
18	300	20	11	320	21	24	300	27	23	300	42	06	290	40	02	170	30	23	200	36	14	190	21	24	18
19	010	14	02	320	25	01	290	30	12	300	26	02	280	26	10	170	29	02	160	24	06	190	30	01	19
20	040	11	01	270	25	02	300	40	02	340	21	24	280	25	12	320	29	06	320	23	21	180	32	22	20
21	050	11	13	190	21	01	230	25	01	240	44G	24	210	29	24	260	24	03	280	30	12	210	20	01	21
22	010	9	08	340	18	22	220	40	24	230	45G	13	230	35	11	190	21	03	280	35	09	170	18	12	22
23	030	12	05	280	24	15	220	43	01	230	47G	12	240	34	15	280	24	19	280	20	10	310	16	01	23
24	210	20	24	280	25	07	220	37	14	260	36G	07	230	32	11	270	25	14	280	15	10	240	15	16	24
25	220	35	01	230	30	13	230	40	04	210	44	21	230	25	03	190	42	20	200	22	14	240	39	17	25
26	330	27	18	270	25	08	220	37	03	220	40	01	270	35	21	200	39	07	350	42	11	M	M		26
27	210	32	16	340	30	19	230	24	11	220	40	02	330	31	11	230	16	06	330	29	01	M	M		27
28	210	23	24	290	24	21	230	25	10	230	36	02	230	34	24	110	21	04	320	21	03	M	M		28
29	170	30	11	290	19	11	250	27	13	280	17	13	230	46	08	270	12	18	210	20	15	M	M		29
30	300	33	07	300	23	02	290	34	20	330	13	03				310	24	12	220	26	12	M	M		30
31	220	29	01				310	20	22	290	15	16				330	28	17					M	M	31
MONTHLY MAX	180	35	22	240	30	18	220	43	01	230	66G	13	230	46	08	240	55G	18	210	49	02	240	39	17	MAX
AVE		22			23			27			37			30			29			30			23		AVE

YEARLY MAX -- 66G MPH ON JAN 11 AT 1300 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1972-73

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	260	10	05	330	29	15	300	35G	01	010	15	19	290	21	15	340	20	02	290	16	02	200	15	16*	1
2	230	15	11	360	21	01	240	34	18	020	15	04	030	16	02	040	14	15	050	26	22	300	20	14*	2
3	360	15	12	310	16	18	230	28	20	220	20	20	M	M		270	13	20	350	27	15	230	20	23	3
4	200	20	17	230	16	20	210	35	07	230	19	23	300	21	06	210	23	21	010	23	15	240	27	02	4
5	300	10	03	240	16	07	230	25	02	240	25	23	290	20	09	300	20	13	350	19	16	140	19	19	5
6	090	11	14	340	20	11	220	30	24	240	26	01	230	27G	23	280	19	12	300	32	11	020	26	14	6
7	220	11	01	230	20	13	220	31	04	240	21	03	250	25	01	280	20	08	160	27	10	340	22	13	7
8	090	10	16	240	25	03	220	30	10	240	23	14	200	9	16	180	20	22	360	35	24	290	28	11	8
9	260	20	16	350	21	07	240	20	15	250	20	01	310	15	23	210	18	04	350	31	01	260	29	14*	9
10	230	36	05*	200	15	20	230	25	19	340	21	14	290	22	13	300	16	18	300	25	11	250	30	11	10
11	220	23	02*	050	14	14	230	25	01	320	20	21	220	20	09	210	21	24	330	9	02	310	21	13*	11
12	250	11	04	190	15	05	230	27	18	290	30	19	340	26	20	180	26	24	300	12	13	200	18	21	12
13	280	16	11	020	11	03	250	25	08	280	45	07	280	14	24	180	30	06	220	26	24	180	15	16*	13
14	220	22	24	210	11	15	330	18	16	290	32	01	280	15	11	300	32G	03	220	35	15	200	14	20	14
15	M	M		340	21	18	300	23	16	260	15	20	040	13	12	310	25	18	330	21	18	360	20	11	15
16	230	30	14*	330	15	01	280	23	20	040	16	12	050	11	15	300	24	15	310	23	24	360	24	11	16
17	250	20	04	190	12	12	290	19	02	280	24	17	020	10	02	230	25	24	310	25	01	350	20	17	17
18	200	13	24	350	13	15*	340	26	11	280	30	04	050	20	20	230	21	01	200	25	13	290	21	14*	18
19	210	19	02	030	10	02	300	40	12	220	35	04	290	25	13	350	10	01	300	35	14	M	M		19
20	220	15	02*	170	20	11	320	29	06	010	19	17	270	21	02	200	26	24	300	33	04	M	M		20
21	M	M		340	15	16	280	29	10	020	19	02	210	16	01	210	41G	09	300	13	08	M	M		21
22	M	M		020	10	04	230	26	13	340	15	19	140	26	10	290	19	07	330	22	11	M	M		22
23	050	10	15*	210	10	05	320	29	07	020	19	03	030	16	14	090	14	20	240	11	14	320	23	12	23
24	180	19	17	340	35	19	240	31	11	020	13	02	310	15	10	010	20	12	240	13	10	310	25	10	24
25	300	14	06	340	30	01	290	26	15	040	7	14	280	24	08	040	14	12	300	20	12	240	25	21	25
26	020	13	01	290	50G	06	290	29	18	140	16	11	290	18	02	250	14	21	300	20	17	320	30	23	26
27	200	11	13	330	35G	02	220	24	24	010	14	14	280	15	02	200	16	10	320	20	01	350	41	06	27
28	220	25	24	300	25	05	220	20	01	300	25	16	240	13	06	200	16	15	250	26	12	350	21	09	28
29	220	29	01	300	41G	19	330	25	24	230	40	23				190	15	18	230	34	05	300	20	02	29
30	200	22	14	300	40	05	310	30	08	240	45G	02				010	14	15	220	19	03*	200	15	02	30
31	090	16	19				30	26	01	230	20	01				300	20	17				220	15	24	31
MONTHLY MAX	230	36	05	290	50G	06	300	40	12	280	45	07	230	27G	23	210	41G	09	230	36	05	350	41	06	MAX
AVE		17			21			27			23			1*			20			24			22		AVE

YEARLY MAX -- 50G MPH ON NOV 26 AT 0600 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1973-74

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	250	14	23	240	40	02	220	42G	24	M	M		240	21	12	230	56	03	210	38	22	240	26	09	1
2	230	25	22	230	32	13	210	45	04	M	M		350	32	05	220	52	11	210	35	02	240	35	12	2
3	230	25	01	230	39	08	02[illegible]	21	19	M	M		280	31	18	210	30	17	360	31	12*	220	36	02	3
4	350	11	07	250	38	24	30[illegible]	25	06	220	34	22	260	36	06	290	30	13	300	24	20*	200	15	18	4
5	320	23	23	250	40	01	30[illegible]	25	02	230	35	17	220	27	01	280	27	15	280	29	09	180	14	19	5
6	230	27	24	260	32	14	290	28	13	290	35	13	290	21	23	230	38	21	300	37	24	300	19	24	6
7	240	22	18	250	30	24	290	35	17	240	30	03	340	24	21	220	47	22	320	25	02	290	25	14	7
8	240	21	12	250	30	04	290	32	10	220	33	23	330	28	19	220	45	02	280	22	12	350	25	08	8
9	220	19	13	250	25	22	290	27	15	240	26	01	300	35	15	130	31	20	180	32	19	240	35	15	9
10	220	15	17	310	20	12	300	35	14	260	33	22	280	25	01	320	30	24*	230	25	06	240	40	15	10
11	320	22	13	310	25	08	240	47G	20	240	35	01	280	24	15	290	45	03	340	35	15	240	26	02*	11
12	300	31	17	250	50	20	290	50	06	240	30	10	230	30	07	260	15	17	320	27	02	M	M		12
13	320	29	01	250	42	01	260	26	21	280	31	21	030	13	15	230	36	23	360	27	14	230	37	18*	13
14	050	15	04	310	40	22	290	30	19	300	31	19	030	15	10	220	40	20	280	24	15	240	28	23	14
15	220	19	19	310	21	10	300	35	09	300	30	04	290	34	24	290	30	12	330	25	03	240	45	04	15
16	300	16	15	260	36G	09*	300	31	16	270	19	01	290	30	05	290	35	04	270	19	01	220	35	15	16
17	280	15	01	270	25	02	290	26	07	330	17	23	220	32	10	280	35	08	350	18	09	200	26	15	17
18	340	14	19	240	32	08	030	23	14	280	30	21	300	35	14	220	25	18	220	17	16	200	25	19	18
19	220	15	24	230	30	01	010	20	20	240	27	08	240	26	14	220	35	16	210	29	14	180	45	16	19
20	250	20	04	010	21	19	310	30	21	200	19	23	020	31	18	220	34	02	300	29	21	040	21	07	20
21	320	19	02	250	30	09	250	26	24	240	20	02	300	35	15	290	25	12	300	20	20	240	27	16	21
22	230	20	22	210	30	14	240	43	08	300	30	15	220	34	08	260	26	04	350	20	01	240	19	19	22
23	240	46	21	230	25	22	030	21	01	340	23	06	290	35	03	300	32	04	210	19	24	270	19	10	23
24	310	31	07	310	30	05	010	30	11	040	14	14	320	22	20	300	26	09	220	29	03	360	15	15	24
25	260	21	05	250	25	19	280	36	10	220	31	10	310	29	07	290	31	08	030	11	16*	340	20	11	25
26	340	16	22	250	17	03	300	22	16	280	25	03	230	27	23	270	20	01	230	34	09	310	15	01	26
27	310	25	15*	290	40	21	260	34	16	320	30	21	230	54	16	240	35	06	220	45	03	230	27	22	27
28	020	25	03	300	33	01	320	40	20	320	30	20	240	31	05	240	46	12	220	19	04	240	32	02	28
29	240	25	07	240	40G	22	280	39	07	300	42	14				290	41	01	200	14	07	240	31	24	29
30	310	26	16	220	32	10	290	32	05	290	41	23				240	40	01	310	14	24	240	35	01	30
31	240	41	24				300	20	14*	290	31	02				340	26	24				210	16	04	31
MONTHLY MAX	240	46	21	250	50	20	290	50	06	300	42	14	230	54	16	230	56	03	220	45	03	240	45	04	MAX
AVE		22			32			31			29			29			34			26			27		AVE

YEARLY MAX -- 56 MPH ON MAR 1 AT 0300 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1974-75

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	340	20	11	300	15	03	320	20	02	170	17	14	220	41	08	290	30	11	200	22	10	320	20	07	1
2	250	14	21	230	20	04	310	16	04	360	27	12	050	14	14	260	21	10	300	31	10	320	19	10	2
3	230	32	24	170	10	02	310	13	01	300	24	09	310	15	07	350	25	04	240	35	23	320	26	10	3
4	240	25	11*	020	15	10	070	10	01	320	38	23	070	10	13	220	31	19	230	42	07	230	25	13	4
5	240	27	10	020	12	01	010	16	18	350	33	04	350	27	18	220	48	02	240	40	01	230	30	08	5
6	220	20	04	030	18	23	310	22	22	250	30G	03	310	29	22	230	35	08	210	45	24	320	30	15	6
7	290	19	07	040	15	01*	310	20	04	250	30G	05	220	29	23	230	27	22	200	40	01	320	25	08	7
8	020	11	09	040	24	08*	020	13	19	210	39	11	230	27	15	220	30	10	310	27	02	260	16	16	8
9	210	16	01	340	19	24	040	14	03	350	23	15	220	40	19	340	21	14	320	17	09	240	17	14	9
10	240	22	06	350	30	23	010	11	21	280	25	16	260	25	16	290	17	12	200	19	09	280	16	09	10
11	150	16	24	310	30	24	290	40	24	300	35G	02	320	35	04	200	19	20	180	21	14	220	18	21	11
12	140	18	02	310	34	08	290	45	01	290	31	22	230	30	21	290	15	17	230	15	03	010	31	24	12
13	190	18	24	290	40G	02	220	30	06	280	32G	13	230	38	06	240	18	24	330	20	22	010	32	04	13
14	340	22	14	310	35	09	340	29	07	280	35	12	120	20	21	130	20	23	260	23	24	360	19	01	14
15	320	18	06	310	28	02	340	29	07	290	22	12	180	19	01	290	16	22	260	30	08	270	15	12	15
16	330	15	01	340	20	02	340	35	06	290	29	10	280	13	12	200	24	21	250	40	05	260	18	24	16
17	040	13	14	320	15	01	250	26	14	290	35	14	290	21	23	200	22	01	250	30	01	240	20	19	17
18	080	11	15	250	35	15	300	26	08	290	40G	17	340	24	13	310	27	12	310	40	22	M	M		18
19	010	18	13	340	25	02	260	34	06	350	31	05	280	35	15	290	30	08	320	30	04	M	M		19
20	250	15	10	310	23	04	260	41G	19	290	34	03	220	31	07	240	32	05	330	16	10	200	41	22*	20
21	200	16	14	250	17	20	200	41G	24	180	20	05	130	16	18	210	42	23	210	20	15	210	47	02	21
22	200	21	24	230	22	06	200	39G	01	320	24	24	330	20	20	210	50	05	260	29	23	200	22	10	22
23	290	14	24	350	28	10	130	26	16	310	27	16	030	22	03	290	41	20	270	20	01	330	24	22	23
24	350	11	02	300	20	04	170	29	01	290	50	17	300	36	16	300	40	03	230	33	24	320	30	07	24
25	180	11	02	240	35	12	190	22	21	290	54G	09	300	25	13	190	30	13	230	36	04	280	33	05	25
26	310	10	07*	280	30	19	190	15	09	240	36	13	280	23	11	190	30	03	220	50	10	250	25	24	26
27	M	M		260	25	13	330	15	02*	220	32	09	280	43	04	180	26	01	340	40	23	250	29	01	27
28	M	M		190	18	12	M	M		210	30	12	290	35	13	320	20	12	010	36	02	090	21	21	28
29	140	29	18*	350	16	17	200	22	01	220	36	10				350	24	14	330	19	16	070	25	04	29
30	220	25	02	330	19	07	290	15	05	220	35	13				290	29	12	270	17	16	030	19	14	30
31	270	21	12				310	16	19	230	25	15				300	26	01				330	20	15	31
MONTHLY MAX	230	32	24	290	40G	02	290	45	01	290	54G	09	280	43	04	210	50	05	220	50	10	210	47	02	MAX
AVE		18			23			24			32			27			28			29			25		AVE

YEARLY MAX -- 54G MPH ON JAN 25 AT 0900 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1975-76

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		050	10	24	310	35	05	030	15	13	290	34	14	230	41	14	230	35	22	290	19	17	1
2	M	M		360	16	16	270	30	06	290	29	23	290	40	16	240	41	18	240	34	07	280	19	10	2
3	M	M		360	21	11	300	14	01	310	25	05	270	41G	01	260	30	05	300	19	09	030	14	16	3
4	M	M		010	8	06	310	18	21	310	32	15	210	41	11	320	19	13	220	23	03	230	20	13	4
5	M	M		060	13	13	010	20	06	250	35	15	220	27	01	320	20	13	140	29	21	300	26	05	5
6	M	M		290	20	13	340	26	13	330	20	15	280	14	13	040	14	05	240	25	19	130	21	21	6
7	M	M		240	24	14	320	24	22	290	27	19	290	30	09	240	14	03	330	23	15	180	19	01	7
8	M	M		230	22	01	310	27	04	290	21	01	240	30	22	320	17	17	190	38	23	180	11	09	8
9	M	M		280	19	12	310	24	14	210	33	22	230	35	05	320	29	13	M	M		340	20	07	9
10	M	M		230	39	10	270	25	14	240	24	02	230	36	01	310	23	09	M	M		220	20	22	10
11	M	M		310	43	17	310	15	06	220	30	20	290	23	07	260	29	02	200	24	24	300	27	20	11
12	M	M		300	26	01	230	34	13	310	32	24	280	27	14	310	20	17	180	33	14	330	31	20	12
13	M	M		320	19	07	230	25	04	280	27	07	210	32	23	360	26	10	190	41	11	330	26	03	13
14	M	M		330	15	13	230	20	01	300	35	24	220	30	01	280	25	15	210	25	02	320	20	02	14
15	M	M		040	15	21	300	53	10	300	35	08	230	19	18	320	27	17	010	20	18	240	15	13	15
16	360	25	17	240	25	24	230	35	07	290	31	05	260	32	22	320	27	12	280	21	09	280	14	15	16
17	360	19	01	230	25	04	300	31	04	300	25	17	300	35	16	320	27	15	340	24	21	350	17	11	17
18	060	15	15	200	20	11	350	21	04	280	22	14	260	40G	09	250	56G	24	320	17	01	240	15	21	18
19	340	11	06	020	19	18	350	16	07	010	17	01	220	26	07	250	46	01	340	24	21	180	21	16	19
20	300	17	10	340	21	04	030	7	02	310	20	05	030	31	12	330	38	07	290	25	17	040	13	09	20
21	290	22	09	210	11	04	050	11	14	330	14	13	310	21	24	320	36	16	240	31G	06	M	M		21
22	250	24	13	040	13	02	220	15	24	280	25	14	300	28	06	250	46	24	220	30	24	300	16	16*	22
23	160	10	03	310	27	18	210	12	01	280	20	09	240	34	24	260	50	07	230	28	02	280	27	10	23
24	290	18	22	300	28	10	340	25	19	350	25	17	240	33	04	250	42	21	290	25	08	290	19	10	24
25	280	20	16	310	31	03	360	19	18	290	25	06	290	24	07	250	39	03	180	31	23	340	23	24	25
26	240	36	13	310	32	07	320	35	24	300	33	10	280	25	11	010	27	01	190	35	07	340	19	02	26
27	250	35	01	270	24	02	300	45	02	350	21	01	290	16	07	250	32	13	210	24	12	280	10	05	27
28	250	20	02	210	27	13	360	19	08	340	26	02	230	33	12	250	20	08	230	19	15	230	20	13	28
29	250	19	18	350	23	24	030	14	08	320	20	11	220	41	24*	040	15	16	250	14	12	360	18	15	29
30	230	17	08	290	47G	06	230	39	14	340	43	18				340	25	15	350	21	18	200	14	04	30
31	230	23	05				140	19	04	330	25	03				340	23	01				360	17	10	31
MONTHLY MAX	240	36	13	290	47G	06	300	53	10	340	43	18	270	41G	01	250	56G	24	190	41	11	330	31	20	MAX
AVE		21			23			24			26			30			30			25			19		AVE

YEARLY MAX -- 56G MPH ON MAR 18 AT 2400 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

Minimum Hourly Winds

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1963-64

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	VAR	8	16	360	2	01*	290	7	19	360	8	06	250	11	14	VAR	2	22	270	5	08	220	2	13*	1
2	310	2	08*	360	4	14*	340	6	12*	290	10	18	VAR	5	05	070	6	21	360	9	24	200	9	09	2
3	290	5	18*	310	3	09*	340	4	08	360	4	23	090	4	12	360	2	03*	360	5	01	220	17	01	3
4	200	4	17*	310	3	01	270	3	22*	310	6	01	VAR	3	08	310	12	08	220	5	16	200	9	20	4
5	220	5	07*	270	7	01	VAR	4	07	VAR	6	03	200	6	16	VAR	3	17	VAR	4	22	200	16	02	5
6	310	4	07*	220	11	22	VAR	6	11	360	9	10	M	M		200	2	18*	020	3	06*	360	5	22	6
7	310	3	07*	040	4	18	290	13	06	220	6	07	M	M		180	2	11	180	4	12*	190	8	06	7
8	VAR	3	08*	VAR	7	10*	VAR	4	20	310	4	05*	340	12	08	360	2	09*	020	5	01*	320	7	18	8
9	250	3	19	290	10	01	VAR	2	19	220	10	18	290	16	04	VAR	4	24	270	5	24	M	M		9
10	310	4	07*	360	7	12*	VAR	2	05	VAR	7	12	360	5	19	270	2	05	250	6	08	M	M		10
11	VAR	4	15	220	6	09*	310	4	08	310	10	07	VAR	5	04	VAR	6	10	250	11	13	M	M		11
12	220	2	09	290	9	03*	VAR	4	11	360	2	18	220	2	15	250	12	01	250	17	19	M	M		12
13	250	4	05	M	M		270	15	03	310	6	02	VAR	4	10*	220	5	04	290	30	12	M	M		13
14	360	4	09*	360	4	03*	020	6	24	360	4	16*	290	3	03*	290	13	10*	VAR	8	24	M	M		14
15	340	2	09*	290	4	12*	020	4	01	270	1	02*	360	4	13	290	9	05	VAR	4	04	M	M		15
16	VAR	5	14*	220	5	10*	250	3	05	360	10	12	VAR	5	01	360	3	07	220	23	17	M	M		16
17	340	4	08*	M	M		310	19	17	250	9	12	290	9	02*	360	3	21*	200	9	03	M	M		17
18	VAR	3	16*	M	M		020	4	12*	340	10	24	M	M		VAR	6	17	220	3	20	M	M		18
19	220	3	02*	M	M		360	7	03	M	M		040	4	24	340	13	08	180	7	07	M	M		19
20	M	M		360	5	04*	VAR	3	22*	M	M		130	2	04	290	8	24	360	3	04	M	M		20
21	M	M		M	M		360	2	01*	M	M		340	10	06	270	5	09	290	5	10	M	M		21
22	360	6	15*	M	M		340	3	06	VAR	2	11	360	6	10	270	11	21	220	8	20	M	M		22
23	340	6	24	M	M		340	10	02	270	12	01	360	6	08	M	M		200	4	07	M	M		23
24	VAR	4	09	M	M		340	5	23	270	13	05	220	5	20	M	M		VAR	4	06	M	M		24
25	270	3	19*	M	M		VAR	5	02	040	3	19	360	6	23	250	12	22	290	10	08	M	M		25
26	020	3	04	M	M		VAR	6	07	VAR	5	16	340	5	02	360	5	24	310	11	07	M	M		26
27	270	5	02*	M	M		290	7	02*	360	7	02	310	14	22	VAR	5	03	310	24	21	M	M		27
28	230	4	13*	270	11	07	310	11	09	VAR	7	18	VAR	6	11	VAR	7	20	VAR	3	20	M	M		28
29	200	4	06*	290	12	23	310	12	22	VAR	3	01	270	8	07	310	12	10	270	1	08	M	M		29
30	270	2	07*	250	6	13	340	10	14	340	6	24				270	9	20	250	2	22*	M	M		30
31	360	4	11*				340	7	01	040	12	11				220	4	10				M	M		31
MONTHLY MAX	VAR	8	16	290	12	23	310	19	17	270	13	05	290	16	04	290	13	10	290	30	12	220	17	01	MAX
AVE		04			06			06			07			06			06			08		09		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1964-65

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		340	8	21	180	2	12*	VAR	7	18	VAR	8	04*	180	7	19*	230	11	06	1
2	M	M		M	M		360	5	20	340	8	04*	270	10	07	M	M		VAR	3	05	190	11	21	2
3	M	M		040	2	24*	290	2	18	220	6	01	290	13	22	270	11	01	VAR	4	17*	M	M		3
4	M	M		M	M		340	2	01*	VAR	6	06*	VAR	6	07	360	8	09	040	2	22	M	M		4
5	M	M		M	M		200	1	24*	270	10	05	VAR	4	18	360	2	17*	270	4	06*	M	M		5
6	M	M		320	7	05	220	1	01*	290	10	17	360	5	20*	310	2	06*	VAR	8	14*	M	M		6
7	M	M		VAR	4	22	M	M		220	13	24	340	2	22*	310	5	08*	VAR	3	06	M	M		7
8	M	M		310	5	21	310	5	13*	M	M		180	4	08*	340	6	06*	VAR	3	09	M	M		8
9	M	M		VAR	4	04	360	3	12*	290	6	08*	360	3	12*	VAR	6	18*	220	8	22	M	M		9
10	M	M		270	9	16*	VAR	4	12	360	3	11*	130	12	22	VAR	4	20	220	6	16*	M	M		10
11	M	M		040	6	06*	VAR	11	16*	040	3	16*	340	5	07	VAR	3	13*	360	6	24	M	M		11
12	M	M		VAR	10	06	VAR	5	08	220	7	01	310	12	21	VAR	3	14*	340	2	02	M	M		12
13	M	M		220	6	01	290	18	22	310	12	13	360	14	16	310	3	02*	200	14	23	M	M		13
14	M	M		VAR	2	02	340	6	08	290	18	04	180	6	21	VAR	8	23	270	10	08	M	M		14
15	M	M		200	8	17	250	20	03	310	15	19	360	3	08*	VAR	6	18*	270	10	20	M	M		15
16	M	M		180	13	14	250	25	05	360	7	10*	020	8	20	180	5	09*	310	9	01	M	M		16
17	M	M		VAR	2	15*	VAR	8	04	340	4	20*	360	6	13*	020	8	22	220	2	20	M	M		17
18	M	M		310	1	09*	340	5	14*	VAR	4	16	360	4	11	340	6	20	VAR	6	10	M	M		18
19	M	M		020	10	01*	VAR	8	12*	020	4	14	340	4	11	360	6	01	290	13	05	M	M		19
20	M	M		M	M		270	7	01	200	3	05	VAR	13	24	290	15	22	310	7	24	M	M		20
21	M	M		M	M		VAR	8	07	VAR	3	15*	270	9	19	VAR	14	17	200	9	02	M	M		21
22	M	M		M	M		VAR	10	02	250	7	01	340	4	23	290	10	24	VAR	9	24*	M	M		22
23	M	M		M	M		360	20	20	290	15	21	360	4	01*	250	3	20*	220	9	04*	M	M		23
24	M	M		340	11	02	VAR	8	06	VAR	8	01	290	19	18	270	4	06	310	6	05	M	M		24
25	040	6	09*	230	11	23	340	11	20	340	6	04*	360	8	22	270	4	07*	180	7	15*	M	M		25
26	M	M		320	5	02	360	8	09	290	16	01	290	7	20*	250	15	01	090	8	09	M	M		26
27	M	M		290	6	05	180	8	24*	VAR	7	16	310	8	01	250	17	04	090	2	09*	M	M		27
28	270	6	20	270	9	03	270	6	21*	VAR	12	23	020	6	13*	VAR	3	18*	M	M		M	M		28
29	300	3	11	300	13	24	220	6	03*	VAR	15	01				VAR	3	10*	250	4	17*	M	M		29
30	190	7	09*	270	8	10	200	11	15	250	22	16				020	5	18*	290	6	12*	M	M		30
31	040	3	18*				070	3	23	270	17	02				270	4	19				M	M		31
MONTHLY MAX	190	7	09	180	13	14	250	25	05	250	22	16	290	19	18	250	17	04	200	14	23	230	11	06	MAX
AVE		05			07			08			09			07			07			07			11		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1965-66

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		020	5	19*	360	4	15*	310	3	08	340	7	07*	020	8	19	340	12	06	220	5	01*	1
2	M	M		340	5	01	360	7	03	M	M		M	M		220	2	07	340	12	21	M	M		2
3	M	M		250	1	19	340	14	01	250	10	17*	360	9	11*	340	16	05	130	3	18	180	4	14*	3
4	M	M		310	4	02*	VAR	7	07	VAR	5	14	270	6	09	340	19	18	180	5	06	360	1	08*	4
5	M	M		200	2	18*	310	4	22	020	7	01	130	4	09*	340	9	06	340	18	01	M	M		5
6	M	M		200	2	01*	250	1	15	340	9	01	270	4	07*	340	1	20	310	1	23	M	M		6
7	M	M		VAR	3	02*	290	1	20	020	5	17	360	2	16*	310	2	01	310	2	01*	M	M		7
8	M	M		340	3	01	200	1	21	270	8	01	070	5	18*	310	5	08	340	1	07	M	M		8
9	M	M		250	1	21	250	2	06*	VAR	5	22	270	2	18*	270	7	10	310	10	16	M	M		9
10	M	M		250	4	09	020	7	15	360	6	22	340	6	10*	360	3	02	VAR	4	08*	M	M		10
11	M	M		340	7	05	340	9	01	VAR	4	01	020	7	09	310	3	10	VAR	1	10*	M	M		11
12	M	M		290	5	05	VAR	3	16	340	6	23*	VAR	2	16*	020	2	12	180	5	19*	M	M		12
13	M	M		M	M		250	2	10*	340	6	07	020	6	07	340	4	10	M	M		M	M		13
14	M	M		VAR	5	06	250	3	09*	360	3	19	270	7	15	340	3	20	M	M		M	M		14
15	M	M		VAR	7	01	200	1	07*	VAR	3	20	250	2	04*	180	4	19	310	5	01*	M	M		15
16	340	4	07	200	3	21	VAR	3	01*	070	1	03*	340	15	05	VAR	24	23	VAR	7	24*	VAR	6	06	16
17	VAR	4	08	VAR	2	03	360	1	16*	020	1	22*	340	13	11	VAR	7	04	310	6	05*	320	4	03	17
18	130	10	05	020	3	15	340	6	08*	040	2	10*	290	2	12	VAR	10	04	160	12	21*	VAR	5	07	18
19	340	8	09	290	7	18	VAR	10	11	290	3	24*	VAR	3	01	310	11	04	VAR	4	09*	320	5	21	19
20	360	4	21	290	9	01	340	14	22*	270	4	07*	270	7	06	160	9	15	310	8	08*	320	9	06	20
21	040	6	09	270	9	15	290	7	15	310	7	01*	340	2	11*	180	8	04	VAR	5	09	320	6	22	21
22	290	3	24	020	4	13	220	7	14	290	2	20	220	1	02*	340	10	01*	180	1	20*	360	8	03	22
23	360	3	05	220	4	08	340	3	12*	VAR	2	12	360	3	08	340	11	22	310	7	08*	320	7	01*	23
24	310	8	23	270	12	01	340	5	10*	340	5	01	VAR	1	07	340	8	09*	220	4	14*	320	6	01*	24
25	360	3	12	VAR	3	11	250	18	21	340	11	20		0	19	VAR	2	10	VAR	9	12*	360	4	22*	25
26	270	6	19	M	M		270	10	14*	360	4	07		0	07	340	8	08*	VAR	11	03	M	M		26
27	360	4	08	270	7	09*	VAR	6	02	290	3	07	360	7	09	310	3	09*	VAR	7	01	M	M		27
28	340	5	21	020	12	03	250	6	09	340	12	03	270	9	16	040	2	24	VAR	8	03*	140	6	10*	28
29	340	4	20	360	8	11	200	26	23	310	6	10				040	5	01	310	6	23*	220	4	20*	29
30	360	3	22*	340	2	10*	200	12	09	VAR	3	11*				340	5	09	VAR	2	08	320	5	12*	30
31	160	3	01				250	8	07	360	4	08*				360	7	10				220	5	16*	31
MONTHLY MAX	130	10	05	270	12	01	200	26	23	340	12	03	340	15	05	VAR	24	23	340	18	01	320	9	06	MAX
AVE		05			05			07			05			05			07			06			05		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1966-67

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		280	6	18	300	3	10	200	4	22	050	7	03*	230	9	21	340	7	21	1
2	M	M		M	M		M	M		330	7	06	340	5	06	210	9	20	240	6	20	040	6	02	2
3	M	M		M	M		030	4	22	330	11	03	350	8	03	220	14	08	230	9	01	330	3	06	3
4	M	M		M	M		280	1	16	040	4	17	300	12	05	240	7	18	280	5	20	090	5	20	4
5	M	M		M	M		280	8	04	240	6	18	220	3	20	220	6	04	230	9	01	230	6	18	5
6	M	M		M	M		240	4	14	030	9	01	030	7	19	230	8	23	230	6	19	360	10	05	6
7	M	M		M	M		310	8	24	340	5	18*	340	8	20	290	9	20	240	4	20	330	12	04	7
8	M	M		M	M		300	8	01	020	6	03	350	10	01	260	9	01	240	6	01	280	8	22	8
9	M	M		M	M		340	4	12	030	4	07	300	11	21	330	9	10	M	M		190	7	21	9
10	M	M		M	M		330	9	24	010	4	01	320	15	19	240	10	12	330	4	11*	230	8	24	10
11	M	M		M	M		350	6	10	010	4	23	270	13	24	240	13	10	200	8	20	220	6	01	11
12	M	M		M	M		320	5	03	010	2	21	300	9	06	240	12	06	200	6	07	180	6	24	12
13	M	M		M	M		330	9	23	240	5	14	030	8	08	240	19	09	010	7	02	190	4	04	13
14	M	M		M	M		280	9	04	240	20	22	040	7	23	250	5	22	240	12	13	330	5	01	14
15	M	M		M	M		280	2	22	240	4	20	300	4	23	270	4	16	200	15	24	290	12	16	15
16	M	M		M	M		330	3	02*	250	5	24	300	4	01	240	3	19	330	6	21	330	8	21	16
17	M	M		M	M		020	1	16	M	M		240	13	06	340	5	21	220	8	05	260	8	21	17
18	M	M		M	M		010	3	08	M	M		020	7	24	360	5	05	160	6	08	270	7	21	18
19	M	M		M	M		010	2	06	M	M		230	4	04	260	6	05	210	7	03	270	8	05	19
20	M	M		M	M		200	2	22	M	M		360	7	10	280	5	22	240	9	21	020	7	04	20
21	M	M		M	M		270	2	07	M	M		300	11	01	260	5	02	280	11	02	330	6	13	21
22	M	M		M	M		020	6	02	M	M		270	13	18	250	7	09	070	4	18	360	8	03	22
23	M	M	230	5	09*	350	1	12	M	M		270	10	23	270	8	09	040	6	12	280	7	04	23
24	M	M	270	6	18	020	1	16	M	M		260	9	24	M	M		210	8	21	210	7	22	24
25	M	M	300	7	16	210	1	05	M	M		280	5	08	M	M		240	5	06	M	M		25
26	M	M	290	11	24	200	4	01	M	M		010	6	11	330	6	05	280	8	05	M	M		26
27	M	M	280	11	24	210	4	09	M	M		360	7	22	040	4	06	210	7	21	M	M		27
28	M	M	310	6	18	350	5	21	M	M		320	6	24	230	12	04	290	11	05	M	M		28
29	M	M	320	4	21	360	5	06	M	M					080	10	23	080	10	22	M	M		29
30	M	M	270	7	23	030	1	02	M	M					270	10	04	030	10	01	M	M		30
31	M	M				310	11	01	210	5	17				190	11	18				M	M		31
MONTHLY MAX			290	11	24	310	11	01	240	20	22	320	15	19	240	19	09	200	15	24	330	12	04	MAX
AVE				07			05			06			08			08			08			07		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1967-68

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		M	M		M	M		360	3	24	040	3	19	160	3	09	310	3	20	1
2	M	M		M	M		M	M		M	M		020	7	24	220	1	03	190	4	07	220	5	23*	2
3	M	M		M	M		M	M		260	13	02	360	5	04	020	2	03	020	8	24	220	4	03	3
4	M	M		M	M		M	M		030	4	07	010	4	04	310	4	16	010	7	21*	240	5	15	4
5	M	M		M	M		M	M		270	4	10	040	5	15	360	1	09	330	5	06	030	2	05	5
6	M	M		M	M		M	M		360	5	11	010	1	02	360	2	18	020	7	18	300	5	05	6
7	M	M		M	M		M	M		010	1	17	030	1	21	010	1	03	310	5	22	240	14	19	7
8	M	M		M	M		M	M		360	2	18*	200	1	08	020	1	14	360	4	01	280	3	15	8
9	M	M	350	4	06	360	7	02	M	M		360	4	02	270	1	09	300	7	12	310	1	19	9
10	M	M	270	10	01	030	7	13	M	M		040	1	10	120	1	01	320	3	19	360	3	01	10
11	M	M	200	2	24	270	14	24	330	4	16	030	2	21	190	4	12	330	2	09	190	2	05	11
12	M	M	280	5	23	360	3	09	360	5	01	230	3	23	280	6	23	200	5	23	030	1	05	12
13	M	M	270	5	01	260	18	20	030	6	01	020	1	04	250	10	03	030	5	22	210	4	07	13
14	M	M	340	5	08	250	7	14	020	2	24	040	1	01	310	6	19	280	7	21	230	3	21	14
15	M	M	280	6	18	130	2	07	020	1	15	030	4	03	360	4	23	260	9	02	310	12	03	15
16	M	M	310	7	03	340	13	18	010	1	01	310	6	17	230	3	03	290	4	08	240	3	08	16
17	M	M	270	3	20	020	9	24	360	4	10	350	9	05	220	9	21	190	6	06	300	8	20	17
18	M	M	260	6	19	090	7	02	350	4	07	310	12	05	330	7	19	190	10	03	300	6	22	18
19	M	M	260	6	02	280	3	24	020	4	11	320	19	03	360	3	09	030	5	07	280	6	08	19
20	M	M	010	5	03	360	3	01*	160	1	16	350	10	06	020	1	08	300	4	08	360	3	12	20
21	M	M	M	M		360	8	04	340	2	01	020	6	18	310	10	01	120	2	24	M	M		21
22	M	M	M	M		300	9	21	020	1	24	330	10	23	350	6	24	190	1	24*	M	M		22
23	M	M	M	M		320	10	01	020	2	01	290	8	19	140	2	11	160	1	02	M	M		23
24	M	M	M	M		350	8	01	030	3	15	270	8	09	290	11	01	280	3	20	M	M		24
25	M	M	M	M		300	12	04	180	1	22	300	4	07	290	4	18	330	4	18	M	M		25
26	M	M	M	M		340	7	24	090	1	15	020	3	15	330	6	24	010	2	13	M	M		26
27	M	M	M	M		260	11	23	250	4	08	180	2	13	040	5	07	020	1	04	M	M		27
28	M	M	M	M		010	3	23	220	7	24	360	11	02	340	6	02	190	2	04	M	M		28
29	M	M	M	M		360	3	01	220	4	01	340	6	18	290	4	12	270	3	22	M	M		29
30	M	M	M	M		040	5	08	270	18	10				270	6	23	270	7	21	M	M		30
31	M	M				020	10	17	330	7	19				290	3	15				M	M		31
MONTHLY MAX			270	10	01	260	18	20	270	18	10	320	19	03	290	11	01	190	10	03	240	14	19	MAX
AVE				05			08			04			05			04			05			05		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
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* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1968-69

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		310	1	04	330	3	22	270	6	24	210	3	12	120	1	15	120	1	23*	120	3	06	1
2	M	M		330	4	16	330	7	01	310	7	08	330	12	03	100	1	22	110	1	07	180	6	07*	2
3	M	M		010	4	01	320	15	14	VAR	3	12	090	3	13	130	1	09	070	5	14	170	1	08	3
4	M	M		350	5	18	020	6	23	040	6	02	180	1	19	170	6	09	090	2	13	180	4	02	4
5	M	M		060	2	21	260	7	16	270	19	20	VAR	3	02	100	1	03	120	1	10	120	4	01	5
6	M	M		070	3	09	270	5	11	240	15	24	140	1	17	110	1	12	200	15	07	090	9	22*	6
7	M	M		020	1	21	220	3	09	120	3	05	200	4	02	170	8	15	070	8	03	M	M		7
8	M	M		300	9	01	300	3	21	270	4	21*	090	4	16	150	1	03	310	10	23	M	M		8
9	090	1	12*	080	7	08	350	3	10	090	4	05	VAR	4	02	140	1	23	090	5	18	M	M		9
10	310	3	22	300	12	24	310	4	04	250	10	23	260	5	19	160	1	01	170	2	21	M	M		10
11	340	1	10*	070	6	19	210	4	20	VAR	6	19	200	5	21	150	1	05	160	1	07	M	M		11
12	240	6	01	310	8	05	320	22	15	110	2	18	120	3	17	300	6	21	110	1	06	M	M		12
13	340	4	03	030	1	09	040	2	09	VAR	3	18	150	1	15	120	3	17	140	1	02	M	M		13
14	210	5	20	030	1	03	310	3	11	090	3	02	180	1	07	110	1	01	160	4	20	VAR	4	19*	14
15	060	6	16	270	3	14	330	6	20	290	4	03	060	1	01	060	1	23	130	4	18	120	1	18	15
16	340	9	22	310	13	17	290	5	04	090	3	19	030	1	01	360	1	19	160	2	23	060	1	24	16
17	340	8	24	320	16	04	040	5	10	120	2	02	360	1	04	VAR	1	01	060	5	06	060	1	01*	17
18	050	2	12	320	13	01	010	13	01	100	1	16	200	1	10	230	4	19	110	3	17	250	6	05	18
19	020	1	14	040	3	21	040	1	08	080	6	10	110	2	19	310	10	04	130	3	07	220	10	16	19
20	260	4	19	330	9	19	300	4	19	290	5	22	060	5	05	150	1	08	VAR	5	23	180	4	04	20
21	330	4	22	360	1	06	020	1	14	090	3	08	110	1	17	140	1	20	160	2	23	180	2	10	21
22	350	7	01	020	5	10	310	10	24	310	8	04	180	1	21	130	1	18	170	3	07	230	5	07	22
23	330	15	07	030	1	07	050	3	15	100	2	05	120	1	09	240	5	01	160	6	08	180	1	01	23
24	360	1	18	300	5	05	090	3	20	110	3	06	200	4	02	VAR	4	03	190	9	04	180	2	21	24
25	050	2	10	340	7	23	210	18	12	220	6	02	250	16	06	340	10	19	340	9	23	200	2	09	25
26	060	5	01	040	1	13	170	3	19	270	7	06	210	6	17	330	11	23	320	8	04	170	1	18	26
27	360	14	06	360	1	19	030	6	05	180	4	06	110	4	18	330	10	06	VAR	3	19	120	2	18	27
28	050	1	19	200	1	02	VAR	3	01	190	5	18	160	1	19	240	9	09	100	4	02	090	2	03*	28
29	200	1	07	050	7	09	210	8	16	190	7	15				340	3	21	280	5	03		0	03	29
30	360	2	05	030	1	15	240	16	07	220	3	03				220	3	15	260	6	06	220	5	07	30
31	270	2	22				050	11	21	VAR	2	20				M	M					200	4	06	31
MONTHLY MAX	330	15	07	320	16	04	320	22	15	270	19	20	250	16	06	330	11	23	200	15	07	220	10	16	MAX
AVE		05			05			07			05			03			04			04			03		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

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CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1969-70

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		140	2	08	020	6	04	320	15	01	270	3	04	020	2	02	210	3	04	1
2	M	M		M	M		090	4	03	360	8	01	280	7	04	VAR	2	24	340	8	23	280	8	23	2
3	M	M		M	M		090	4	07	300	14	02	280	13	17	320	2	01	040	1	05	270	5	21	3
4	M	M		090	1	21	250	7	03	090	3	17	270	12	22	250	5	17	340	8	03	190	1	24	4
5	M	M		290	4	01	150	1	18	200	5	02	280	12	08	030	1	15	350	13	22	200	1	01	5
6	M	M		090	3	19	030	8	11	330	11	10	320	14	12		0	01	120	1	12	250	2	06	6
7	M	M		180	5	18	340	8	10	250	18	18	330	11	22	360	8	06	310	5	03	010	4	07	7
8	M	M		130	1	16	090	4	11	320	12	19	330	10	20	040	3	02	250	4	03	030	4	05	8
9	M	M		170	1	12	180	2	17	VAR	6	09	350	5	21*		0	21	330	1	12	300	9	12	9
10	M	M		360	6	09	090	4	04	030	16	09	340	7	02		0	06	310	5	03	300	5	04	10
11	M	M		090	6	01*	260	10	01	330	10	18	300	6	04		0	01	270	1	10	170	5	18	11
12	M	M		M	M		050	10	19	320	10	09	060	4	21	010	4	01	310	9	22	240	5	17	12
13	M	M		290	25	02	320	6	17	350	6	22	250	10	01	300	12	21	090	2	07	260	1	01	13
14	M	M		320	13	23	090	7	24	050	10	12	070	2	02	270	3	22	200	11	02	300	4	02	14
15	M	M		090	5	13	VAR	3	17	060	3	10	320	10	21	250	2	10	220	6	24	320	10	20	15
16	M	M		VAR	6	10	090	4	09	090	4	06	330	6	19		0	04	160	1	05	300	4	22	16
17	M	M		190	8	05	VAR	3	20	320	14	16	330	9	20	330	7	21	160	5	18	250	8	21	17
18	M	M		320	12	02	070	1	11	280	11	24	330	7	12	350	4	23	240	6	05	240	7	19	18
19	M	M		090	8	12	060	1	01	250	16	02	030	1	21	100	1	06	360	4	20	200	7	09	19
20	M	M		110	4	20	VAR	6G	04	270	7	04*	210	1	24	060	2	09	290	10	01	230	7	08	20
21	M	M		090	5	11	230	6	15	280	12	24	090	1	22	020	6	08	270	4	24	150	5	12	21
22	M	M		140	3	22	340	8	20	260	12	01	260	2	02	310	3	22	250	7	19	170	1	04	22
23	M	M		130	2	09	080	2	06	240	10	20	180	1	08	270	8	03	360	4	05	050	1	20	23
24	M	M		090	5	19	210	5	07	360	11G	22	110	1	05	270	6	18	350	4	02	310	1	02	24
25	M	M		120	2	05	220	6	21	240	8	14	340	2	05	050	6	02*	310	10	01	M	M		25
26	M	M		210	6	22	040	5	19	070	4	08	310	10	24	090	1	10	230	14	24	M	M		26
27	M	M		090	4	13	030	2	04	250	14	12	060	1	22	210	1	14	060	4	24	M	M		27
28	M	M		090	3	15	360	2	24	360	7	04	290	4	08	010	2	19	060	5	01	M	M		28
29	M	M		090	5	09	030	5	01	300	14	20				020	1	05	300	5	03	M	M		29
30	M	M		090	4	02	020	8	11	320	4	17				180	13	20	340	4	23	M	M		30
31	M	M					020	8	24	270	6	14				220	3	23				M	M		31
MONTHLY MAX				290	25	02	260	10	01	250	18	18	320	15	01	180	13	20	230	14	24	320	10	20	MAX
AVE					06			05			09			07			04			05			05		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
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BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1970-71

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		010	4	23	250	7	15	090	1	22	330	1	12	M	M		290	15	24	190	4	24	1
2	M	M		040	2	03	230	20	21	190	2	01	280	4	22	M	M		270	12	19	190	7	01	2
3	M	M		030	6	23	330	5	13	170	13	14	010	4	11	M	M		240	4	23	260	1	22	3
4	M	M		230	1	02	010	7	21	020	1	06	290	9	17	M	M		320	5	04	180	5	08	4
5	M	M		090	4	20	010	7	15	350	8	10*	020	9	18	M	M		350	5	22	200	5	22	5
6	M	M		260	5	16	090	2	11*	M	M		020	6	01	M	M		270	2	17*	190	5	03	6
7	M	M		180	6	09	360	2	15	M	M		310	11	03	M	M		050	7	13	150	4	22	7
8	M	M		320	20	23	210	2	23*	300	12	09*	340	15	18	M	M		090	2	15*	330	2	24	8
9	M	M		270	10	22	M	M		290	2	19	010	10	14*	M	M		M	M		260	6	01	9
10	M	M		300	10	04	020	11	21*	290	10	02	310	20	09	M	M		M	M		340	5	22	10
11	M	M		010	5	14	030	5	15	260	12	02	270	19	01	M	M		230	15	12*	240	1	23	11
12	M	M		270	4	12	M	M		220	22	19*	360	6	23	260	7	05	M	M		230	1	24	12
13	M	M		010	1	06	M	M		240	15	17	330	10	01	VAR	5	16*	M	M		290	5	14	13
14	M	M		020	10	21	M	M		360	6	02	030	5	13	M	M		M	M		340	5	07	14
15	M	M		020	5	11	M	M		090	7	13	030	4	01	M	M		M	M		260	5	02	15
16	M	M		330	5	09	M	M		020	10	07	240	3	20	M	M		M	M		250	5	05	16
17	M	M		360	6	24	M	M		250	12	09	220	5	17	300	14	14	300	3	24	250	5	08	17
18	M	M		050	3	18	040	1	04	350	10	16	240	1	08	350	19	08	160	1	04	030	4	03	18
19	M	M		270	7	23	250	11	04	350	14	06	260	2	14	320	12	22	270	3	22	230	9	19	19
20	M	M		040	6	10	090	3	16	310	14	22	190	14	19	080	7	02	290	10	07	190	5	20	20
21	M	M		270	18	09	360	6	07	290	5	09	230	5	17	360	5	08	040	2	17*	170	3	06	21
22	090	5	02	360	8	24	350	12	20	020	7	21	300	2	23*	270	11	22		0	01	340	6	19	22
23	090	6	24	330	13	01	VAR	7	21	060	7	05	020	9	12	250	11	15		0	01	340	6	03	23
24	050	6	04	270	6	10	230	15	07	350	13	07	030	6	22	330	9	24	M	M		250	10	20	24
25	200	6	21	250	15	05	040	5	20	210	6	06	360	7	19	350	10	02	M	M		170	4	20	25
26	350	2	23	010	5	16	090	3	06	350	11	11	340	10	19*	250	15	16	M	M		260	5	12	26
27	010	3	02	050	4	21	280	9	23	340	6	20	M	M		070	5	21	M	M		120	5	18	27
28	360	14	05	260	6	01	M	M		360	8	04	M	M		290	M	20	090	2	17*	320	6	24	28
29	320	16	23	VAR	4	07	M	M		320	15	04				330	11	12	300	10	07*	150	4	06	29
30	330	9	18	250	20	10	M	M		320	25	14				340	7	07	250	5	16	310	9	01	30
31	300	12	04				M	M		300	2	23				300	15	11				300	5	06	31
MONTHLY MAX	320	16	23	320	20	23	230	20	21	320	25	14	310	20	09	350	19	08	290	15	24	250	10	20	MAX
AVE		08			07			07			10			08			10			05			05		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1971-72

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		030	3	01	210	1	08	330	19	02	210	5	19	030	8	24	290	15	01	090	5	07	1
2	M	M		360	10	10	090	2	18	VAR	11	22	030	9	01	290	6	07	240	13	13	320	6	22	2
3	M	M		310	19	19	VAR	4	02*	210	9	22*	300	19	06	330	14	19	280	11	20	300	6	18	3
4	M	M		350	17	01	220	3	20	020	11	08*	330	6	23	350	14	20	VAR	7	23	130	7	18	4
5		0	09*	VAR	6	19	300	4	01	240	20	05	090	6	03	300	20	13	320	10	09	170	2	16	5
6	180	3	20	030	8	17	260	4	23	290	10	22	030	6	21	260	21	22	330	11	16	080	10	19	6
7	040	5	09	060	3	17	VAR	2	02	090	5	10	350	12	20	300	11	19	250	6	19	170	4	05	7
8	030	5	04	030	9	24	210	4	02	330	10	20	VAR	5	22	320	5	19	160	9	10	M	M		8
9	050	7	12	250	6	10	VAR	2	20	010	13	09	VAR	4	18	330	9	06	220	11	17	M	M		9
10	060	3	24	240	9	17	290	6	15	340	19	21	180	4	11	300	9	05	220	18	04	210	3	23	10
11	270	6	08	360	5	04	VAR	2	04	240	19	03	020	6	01	340	6	20	240	19	09	180	5	03	11
12	300	6	21	200	5	19	VAR	5	06	240	25	12	340	11	18	010	5	19	180	19	02	300	11	08	12
13	300	5	10	090	5	19	100	1	13	270	11	22	030	10	10	300	5	23	180	4	18	350	10	22	13
14	090	6	10	180	9	17	VAR	5	03	290	16	01	060	6	23	060	6	03	010	5	19	060	5	07	14
15	230	10	14	160	10	18	270	5	23	360	10	05	020	6	03*	350	14	03	350	11	01	210	4	24	15
16	210	9	06	VAR	1	21	270	10	01	260	5	18	M	M		310	16	05	050	5	07	240	2	07	16
17	030	6	24	060	1	24	040	4	10	080	6	01	330	25	04	270	13	20	230	10	19	090	2	22	17
18	330	9	02	200	4	01	330	8	01	260	10	16	010	9	22	200	9	20	190	9	03	180	2	07	18
19	060	5	14	040	9	23	360	12	23	VAR	6	08	040	6	02	210	6	10	210	5	22	190	8	06	19
20	190	3	23	030	7	17	330	19	10	060	5	01	010	7	21	330	14	14	180	3	04	160	9	08	20
21	180	1	18	030	5	08	230	5	09	010	12	04	160	5	10	200	10	19	280	6	19	020	9	05	21
22	190	2	01	010	7	20	090	8	06	240	22	06	240	11	21	VAR	4	06	300	5	23	150	5	07	22
23	090	3	23	010	9	10	260	8	24	280	14	22	270	10	22	180	4	07	270	4	23	270	4	22	23
24	030	5	01	300	6	23	030	2	03	240	11	17	250	14	03	040	5	01	230	5	01	270	4	01	24
25	VAR	4	10	270	6	01	270	14	09	220	25	10	060	9	06	090	5	07	190	10	01	230	1	05	25
26	220	3	04	300	9	19	270	7	21	200	14	19	250	11	18	VAR	4	19	320	12	03	M	M		26
27	200	10	21	260	10	08	VAR	4	20	210	13	07	300	15	05	150	1	18	330	12	17	M	M		27
28	210	8	14	240	M	16	210	7	01	030	11	14	290	16	07	150	7	09	280	13	22	M	M		28
29	060	6	20	060	5	03	060	6	08	300	7	22	250	14	16	VAR	1	09	260	10	08	M	M		29
30	360	7	18	040	2	18	270	8	03	060	5	16				300	10	01	350	8	05	M	M		30
31	040	3	21				020	5	08	350	5	07				290	14	24				M	M		31
MONTHLY MAX	230	10	14	310	19	19	330	19	10	240	25	12	330	25	04	260	21	22	240	19	09	300	11	08	MAX
AVE		05			07			06			12			10			09			10			05		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1972-73

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	090	2	07	040	7	01	310	15	10	280	2	06	040	4	01	040	4	16	300	1	14	220	6	08•	1
2	080	1	05	020	5	24	360	8	21	040	4	13	010	6	18	040	4	05	090	6	06	020	6	05•	2
3	050	3	16	020	3	03	330	10	01	030	2	02	M	M		VAR	3	15	050	5	02	250	5	19	3
4	030	2	14	180	1	09	330	3	24	030	3	19	350	3	16	VAR	2	08	350	2	01	300	4	22	4
5	060	2	17	300	2	23	050	4	20	330	4	07	020	3	20	360	3	24	030	3	10	270	3	06	5
6	180	1	03	010	3	01	240	15	01	300	5	24	240	2	16	360	4	01	330	4	18	180	4	01	6
7	230	1	03	040	5	17	200	13	24	090	4	07	030	4	23	080	4	01	070	1	01	280	9	21	7
8	360	1	01	030	6	23	140	1	23	300	2	18	280	1	07	210	9	08	040	6	01	280	12	04	8
9	280	6	01	020	9	21	190	1	02	360	1	14	060	1	04	240	2	19	300	13	19	VAR	5	07•	9
10	230	13	01•	030	2	15	020	3	02	070	4	01	340	5	20	360	5	07	350	8	20	280	11	20	10
11	270	2	20•	150	1	20	050	4	11	030	6	05	250	5	04	190	7	21	240	1	20	350	5	23•	11
12	030	1	20	220	4	20	300	8	14	350	11	01	330	9	09	220	7	06	050	2	01	320	2	01	12
13	050	4	17	030	2	19	060	5	16	340	20	15	310	4	21	130	8	11	090	3	01	VAR	3	05•	13
14	310	1	03	090	3	02	020	6	01	340	5	08	080	1	24	030	6	20	040	1	21	280	6	24	14
15	M	M		090	2	02	040	9	02	030	4	07	050	1	22	030	6	08	210	3	13	300	7	01	15
16	030	6	21•	250	1	21	300	4	08	290	5	21	090	1	10	360	9	23	260	12	12	090	1	19	16
17	350	3	21	090	1	10	330	4	09	350	5	01	270	2	09	VAR	4	08	060	1	20	320	10	08	17
18	050	1	01	340	2	10•	360	10	01	300	5	18	040	2	13	190	7	16	190	5	05	310	10	01•	18
19	190	3	08	090	1	18	020	10	07	010	7	21	030	4	19	050	1	04	350	11	01	M	M		19
20	330	1	22•	200	9	03	310	14	16	050	2	04	300	5	20	190	1	02	VAR	1	22	M	M		20
21	M	M		020	1	05	350	9	06	020	6	24	070	3	18	160	5	12	050	4	17	M	M		21
22	M	M		170	1	23	330	9	04	010	4	12	220	9	01	300	5	18	300	7	02	M	M		22
23	020	4	20•	320	1	19	020	7	24	020	9	17	240	6	03	040	1	05	VAR	1	24	340	13	07	23
24	170	1	23	360	6	01	360	4	05	180	1	07	060	1	18	350	5	02	VAR	1	05	260	10	19	24
25	010	3	04	310	16	21	340	14	04	060	1	01	040	6	03	070	1	06	200	4	07	VAR	5	23	25
26	090	3	15	290	15	02	030	7	05	200	1	21	300	3	17	360	3	18	060	1	09	010	7	03	26
27	300	2	03	330	5	24	260	7	17	090	1	09	050	2	22	280	4	04	270	10	16	010	14	24	27
28	290	3	01	030	9	20	090	1	15	020	9	02	050	1	11	210	1	06	VAR	5	20	350	13	04	28
29	210	9	17	340	12	02	090	3	13	250	12	17				210	3	24	VAR	4	01	230	7	19	29
30	220	4	19	330	19	10	350	16	20	050	2	23				220	1	02	200	10	06•	200	4	09	30
31	210	3	01				090	1	18	200	2	10				030	7	08				030	1	04	31
MONTHLY MAX	230	13	01	330	19	10	350	16	20	340	20	15	330	9	09	210	9	08	300	13	19	010	14	24	MAX
AVE		03			05			07			05			03			04			05			07		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
• = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1973-74

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	250	5	21	270	5	21	360	1	06	M	M		290	10	05	290	10	08	240	10	12	300	9	12	1
2	360	6	05	270	5	02	090	9	12	M	M		350	15	12	350	19	24	160	4	11	250	6	22	2
3	330	5	06	090	11	24	220	2	09	M	M		350	14	12	090	5	04	340	17	23•	280	5	09	3
4	290	2	20	060	6	08	320	11	19	250	18	14	310	12	09	300	10	03	320	8	07•	VAR	3	01	4
5	260	5	01	090	7	11	020	13	23	190	13	15	200	3	07	030	7	12	300	9	22	230	1	05	5
6	250	9	14	270	9	06	020	11	22	270	13	06	VAR	1	05	040	8	02	240	10	17	300	8	13	6
7	240	8	08	320	9	22	360	14	11	280	10	12	VAR	1	10	210	18	13	330	13	18	270	14	01	7
8	180	6	19	300	15	08	320	13	07	060	9	12	020	8	14	330	4	21	280	9	19	300	9	21	8
9	080	3	17	090	1	07	320	15	06	280	4	06	330	6	20	210	5	03	240	8	07	280	9	04	9
10	VAR	1	02	290	6	18	330	9	08	330	5	03	340	5	23	150	8	12•	300	8	08	270	10	24	10
11	360	4	23	030	6	13	330	8	15	360	5	22	360	7	06	010	7	24	340	10	02	260	10	06•	11
12	030	7	01	090	5	07	090	10	17	270	5	01	280	9	09	010	2	08	VAR	1	18	M	M		12
13	050	7	23	250	18	17	240	1	05	040	5	04	090	5	07	310	5	01	VAR	3	01	300	13	11•	13
14	030	4	15	290	11	08	060	8	08	300	4	11	030	8	17	280	14	23	330	10	19	070	4	05	14
15	090	5	12	300	1	06	340	15	20	330	6	12	020	5	06	320	13	04	280	13	19	220	20	21	15
16	250	9	02	360	1	22•	300	11	18	330	3	10	270	12	14	270	11	23	260	6	20	210	11	19	16
17	VAR	1	20	090	1	20	050	7	24	280	5	07	060	13	06	280	11	20	220	5	21	210	6	06	17
18	010	6	08	090	4	22	030	4	24	220	3	08	020	10	02	270	5	08	360	2	20	210	3	04	18
19	060	5	08	090	1	05	080	1	02	080	11	03	350	9	18	330	6	11	210	2	02	210	9	01	19
20	350	7	22	070	5	04	050	11	06	190	1	19	040	15	10	080	5	19	030	5	02	350	6	24	20
21	180	4	17	030	1	12	030	8	12	270	5	04	010	10	07	270	10	01	350	8	17	280	10	20	21
22	310	6	02	200	1	21	010	8	19	360	10	01	260	14	19	250	10	18	280	1	16	240	4	24	22
23	220	14	01	300	4	12	020	12	05	320	1	22	350	16	06	090	6	21	210	2	08	240	3	01	23
24	060	5	19	230	1	22	020	10	22	020	5	21	360	6	10	300	10	02	180	2	20	310	5	07	24
25	VAR	4	18	VAR	1	07	020	9	24	030	5	13	360	5	12	240	9	18	190	1	20•	360	5	01	25
26	VAR	3	08	090	1	20	030	6	02	040	6	18	290	11	01	220	3	16	210	9	01	320	10	19	26
27	010	14	08•	030	11	01	280	7	01	330	6	01	260	10	20	330	9	01	090	5	21	340	11	16	27
28	050	6	18	340	7	15	250	21	01	040	10	04	270	10	23	270	15	01	030	5	06	310	6	22	28
29	090	5	18	240	17	03	290	18	03	340	19	06				270	15	16	180	2	14	220	9	02	29
30	040	4	02	030	3	16	040	5	09	330	18	20				300	10	20	020	4	07	080	7	05	30
31	270	9	17				270	9	21•	270	10	22				250	5	05				090	4	08	31
MONTHLY MAX	220	14	01	250	18	17	250	21	01	340	19	06	350	16	06	350	19	24	340	17	23	220	20	21	MAX
AVE		06			06			09			08			09			09			06			08		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
• = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1974-75

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	280	6	20	090	1	17	360	1	15	120	2	05	090	5	20	090	4	23	210	10	01	090	4	24	1
2	270	6	19	180	4	11	050	3	11	360	10	18	090	1	12	060	3	06	260	6	24	060	3	01	2
3	050	4	19	230	1	20	060	2	12	090	9	20	VAR	3	20	310	7	02	060	6	01	360	7	05	3
4	150	9	22*	030	7	01	360	5	10	030	9	04	330	1	09	250	11	14	230	15	16	220	8	22	4
5	320	3	24	130	1	09	180	1	03	350	10	20	340	2	06	050	8	20	210	10	19	220	5	05	5
6	350	4	19	210	2	01	360	13	03	260	9	12	330	15	02	340	7	23	210	16	11	310	10	22	6
7	310	8	19	070	4	16*	040	1	10	280	14	09	330	14	05	320	6	18	090	3	13	320	9	19	7
8	170	3	19	050	2	02*	010	4	02	330	5	22	240	10	03	060	2	18	340	13	24	090	2	07	8
9	300	3	22	200	4	07	030	4	21	270	5	04	230	10	01	180	1	24	060	1	20	230	4	02	9
10	180	3	19	360	6	11	040	2	11	010	10	04	160	4	10	190	6	02	200	7	18	090	4	19	10
11	250	4	04	090	6	07	030	6	01	320	21	09	350	12	22	220	1	24	220	11	24	270	6	02	11
12	170	3	17	310	15	19	010	6	05	040	13	16	360	6	02	360	2	07	080	2	16	020	7	11	12
13	010	1	20	330	23	13	350	7	01	090	10	01	330	10	11	310	3	19	250	3	04	350	13	19	13
14	360	4	22	320	14	17	320	15	20	290	15	24	060	2	07	030	3	16	300	10	15	270	5	17	14
15	360	6	19	310	11	10	030	13	03	090	4	16	VAR	1	22	030	1	07	230	5	22	330	4	10	15
16	010	4	23	040	9	06	350	17	15	260	13	01	360	3	11	330	4	07	230	19	01	230	4	21	16
17	160	2	02	060	4	12	360	10	07	330	13	05	170	6	01	050	6	04	260	4	13	230	5	16	17
18	300	2	08	010	8	24	270	6	24	330	20	02	330	10	09	030	6	23	300	5	07	M	M		18
19	310	3	02	350	13	11	260	7	01	320	14	24	010	9	01	240	10	16	240	2	20	M	M		19
20	VAR	1	17	320	10	20	300	10	10	280	12	11	340	10	23	090	10	03	050	3	01	230	20	09*	20
21	250	3	15	350	5	17	230	9	16	240	4	03	040	4	13	090	1	04	230	6	03	230	13	24	21
22	200	6	13	300	3	08	270	5	21	020	11	06	200	6	06	340	16	24	290	14	17	090	3	07	22
23	090	1	08	310	5	01	340	3	03	300	9	07	040	9	24	330	19	14	040	5	24	340	10	04	23
24	040	3	19	330	9	12	020	3	02	300	15	01	020	10	01	310	9	24	080	5	08	290	8	13	24
25	200	1	05	240	11	06	050	1	14	270	24	24	300	6	23	200	6	07	220	20	24	270	10	11	25
26	360	1	17*	350	10	06	150	1	12	250	20	11	360	6	04	030	4	13	230	11	01	090	3	08	26
27	M	M		020	7	24	030	6	14*	200	13	06	340	9	19	270	6	08	080	13	10	080	6	17	27
28	M	M		050	2	22	M	M		200	9	06	280	13	23	350	7	02	360	7	21	220	6	01	28
29	210	8	24*	040	5	22	050	1	08	230	17	18				030	10	04	030	6	14	360	6	24	29
30	300	7	22	030	9	01	020	4	01	190	9	17				340	9	10	230	5	24	210	3	01	30
31	070	8	07				130	1	08	210	11	01				240	6	09				020	2	18	31
MONTHLY MAX	150	9	22	330	23	13	350	17	15	270	24	24	330	15	02	330	19	14	220	20	24	230	20	09	MAX
AVE		04			07			06			12			07			06			08			07		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1975-76

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M			0	05	280	10	20	060	5	11	090	8	08	220	18	22	090	4	08	040	2	05	1
2	M	M		040	6	08	270	7	02	360	7	20	330	16	19	200	3	07	VAR	3	20	270	4	21	2
3	M	M		250	5	22	090	1	05	040	5	20	020	9	05	090	4	24	270	3	18	210	4	07	3
4	M	M		360	1	09	080	2	15	340	8	11	220	17	13	230	4	01	030	3	20	280	7	05	4
5	M	M		050	1	09	050	2	11	030	4	08	240	4	21	360	5	03	180	2	02	VAR	6	14	5
6	M	M		350	7	09	030	7	04	350	9	06	090	3	21	280	2	20	290	9	22	190	10	05	6
7	M	M		320	6	05	010	8	07	360	7	05	280	8	02	240	1	01	360	1	24	VAR	1	06	7
8	M	M		090	3	21	350	14	24	090	5	21	300	9	20	260	2	01	VAR	1	03	210	2	19	8
9	M	M		290	1	02	350	6	07	230	13	17	230	14	23	360	10	02	M	M		VAR	1	21	9
10	M	M		090	6	01	280	8	23	010	9	19	030	9	16	360	4	14	M	M			0	07	10
11	M	M		310	9	01	060	3	13	010	9	08	320	12	04	040	8	22	180	3	09	350	6	08	11
12	M	M		030	10	07	080	3	03	300	6	09	090	7	04	080	3	09	200	6	19	320	17	02	12
13	M	M		030	4	19	230	1	21	020	4	17	020	3	14	030	8	19	200	1	03	320	15	17	13
14	M	M		090	4	17		0	12	090	8	04	280	7	08	330	4	18	170	8	12	330	5	20	14
15	M	M		030	5	13	350	13	01	310	21	09	030	1	11	350	13	02	350	5	03	190	5	21	15
16	340	14	23	250	8	16	280	14	21	090	6	22	360	6	09	010	10	23	330	3	23		0	07	16
17	060	5	19	220	4	20	030	5	17	340	9	01	330	10	21	020	9	24	VAR	4	03	300	8	24	17
18	090	3	07	160	3	05	120	1	12	090	4	10	320	5	01	340	15	03		0	21	090	4	17	18
19	330	4	09	160	4	04	070	4	14	030	4	05	170	4	23	030	14	13	030	4	01	VAR	2	23	19
20	090	4	02	210	2	23	060	2	18	010	5	20	090	4	09	300	5	21	320	11	05	220	2	21	20
21	330	5	19	250	1	05	030	3	23	360	5	11	010	6	21	300	15	06	290	9	20	M	M		21
22	270	7	06	010	4	17	030	4	07	020	7	09	360	9	12	270	9	19	240	9	18	310	6	08*	22
23	060	3	23	360	6	10	220	2	04	330	5	21	090	4	05	290	12	24	060	4	11	300	5	24	23
24	060	1	02	270	13	21	050	2	10	090	1	05	040	8	09	300	9	01	VAR	6	20	180	4	20	24
25	010	3	01	060	9	07	360	6	08	320	9	01	270	8	18	080	9	16	180	6	08	230	5	05	25
26	090	7	02	360	5	15	350	7	03	320	10	02	090	5	10	300	6	24	190	9	01	300	4	14	26
27	210	7	09	230	2	16	350	19	24	340	6	22	360	4	14	270	5	01	190	6	23	330	3	10	27
28	270	5	20	090	4	20	060	6	10	030	4	14	330	8	23	080	4	21	210	1	24	220	5	21	28
29	020	6	04	010	1	04	050	9	01	340	8	07	030	9	07*		0	06	190	1	01	240	4	07	29
30	240	2	21	090	15	23	060	4	05	280	11	01				320	8	04	VAR	2	03	VAR	1	15	30
31	180	1	08				090	2	13	010	10	16				090	5	16				310	1	23	31
MONTHLY MAX	340	14	23	090	15	23	350	19	24	310	21	09	220	17	13	220	18	22	320	11	05	320	17	02	MAX
AVE		05			05			06			07			07			07			04			05		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

y Peak Wind Gusts

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT. WINTER 1969-70

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		M	M	M	020	12	2340	340	25	1638	340	56	0921	220	35	2133	310	52	2143	M	M		1
2	M	M		M	M	M	360	15	2326	290	35	0211	310	54	1608	220	42	0734	250	48	0046	M	M		2
3	M	M		M	M	M	180	21	1748	290	64	1037	250	52	1718	220	35	1346	360	26	1807	M	M		3
4	M	M		310	26	1110	290	32	1431	220	62	0218	220	58	0948	250	33	0149	290	30	1557	M	M		4
5	M	M		040	12	1845	360	20	2350	340	34	1614	250	46	0526	250	25	0001	290	46	0758	M	M		5
6	M	M		250	16	2139	290	33	1532	270	36	2021	290	46	0520	310	35	1644	220	26	2208	M	M		6
7	M	M		220	46	2238	290	32	1925	250	52	1649	340	36	0502	290	30	1437	250	42	2117	M	M		7
8	M	M		290	33	0022	270	43	1322	290	44	0022	340	38	1332	220	38	2348	290	41	1202	M	M		8
9	M	M		200	28	0232	250	22	2115	340	43	1726	310	26	0650	220	41	1227	310	15	2312	M	M		9
10	M	M		250	44	0107	290	48	1337	270	64	0405	290	29	1401	220	30	0047	250	45	1623	M	M		10
11	M	M		290	40	1310	270	48	0335	290	40	0206	310	25	2305	040	20	1304	220	50	0415	M	M		11
12	M	M		310	58	1755	270	46	0031	290	44	2255	290	32	0317	310	32	2357	310	34	1307	M	M		12
13	M	M		310	63	1717	290	48	0033	270	55	0922	220	38	1326	310	45	1606	180	30	2211	M	M		13
14	M	M		310	53	0154	290	24	0800	270	36	1242	290	20	0814	310	37	0157	200	70	1118	M	M		14
15	M	M		310	27	0044	270	18	0521	340	30	1351	310	36	2359	250	26	0331	220	45	1144	M	M		15
16	M	M		220	48	1444	220	46	1951	200	48	1954	290	53	0844	310	30	2315	090	38	2027	M	M		16
17	M	M		340	39	1522	250	40	0502	270	54	0803	220	67	1012	290	30	2334	180	47	1012	M	M		17
18	M	M		310	34	1202	270	20	0108	310	49	0630	290	38	0448	360	31	0450	310	40	0750	M	M		18
19	M	M		290	50	2022	250	33	2037	220	84	0940	040	16	1433	310	20	1648	340	35	0120	M	M		19
20	M	M		310	42	0507	290	72	0912	250	60	2237	200	18	1413	040	13	1517	220	45	1822	M	M		20
21	M	M		220	22	0610	220	68	2359	290	59	0445	220	25	0145	310	30	1456	220	41	0018	M	M		21
22	M	M		360	18	0347	220	73	0010	290	72	1632	160	25	1925	310	45	0522	250	40	0135	M	M		22
23	M	M		310	17	2220	220	64	1957	310	58	0222	220	17	0014	290	55	1453	310	27	1613	M	M		23
24	M	M		270	34	1229	290	61	1943	220	86	1545	200	15	2022	250	80	1058	220	35	2244	M	M		24
25	M	M		270	28	2201	220	51	2220	220	64	2133	290	25	2331	360	50	0818	310	50	0218	M	M		25
26	M	M		290	28	0126	220	67	0845	220	71	2247	310	27	0252	310	34	0340	220	53	2141	M	M		26
27	M	M		340	14	0457	110	16	0747	220	76	0427	270	16	1631	130	30	0228	200	46	1912	M	M		27
28	M	M		020	12	0010	180	23	1541	290	55	1058	220	35	2318	340	20	1345	220	50	0908	M	M		28
29	M	M		360	14	1935	340	26	2000	290	53	0958				130	38	2133	250	20	2122	M	M		29
30	M	M		020	16	0637	360	38	1432	290	34	0025				130	49	0345	040	21	0842	M	M		30
31	M	M					340	32	0627	270	36	2336				200	22	1826				M	M		31
MONTH MAX				310	63	1717	220	73	0010	220	86	1545	220	67	1012	250	80	1058	200	70	1118				MAX
AVE					32			38			52			35			35			40				AVE

YEARLY MAX -- 220 86 MPH ON JAN 24 AT 1545 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1970-71

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		360	36	0614	220	60	0240	220	43	0354	290	27	0035	M	M	M	290	52	0216	M	M		1
2	M	M		360	30	2238	220	86	1509	200	50	1952	220	40	1820	M	M	M	290	44	1231	M	M		2
3	M	M		360	34	0152	290	65	0518	180	41	0141	220	51	0331	M	M	M	290	47	0422	M	M		3
4	M	M		220	15	0904	220	61	0117	290	28	1738	290	69	2352	M	M	M	290	34	1455	M	M		4
5	M	M		250	45	2251	290	41	0130	310	23	1500	310	72	0809	M	M	M	290	41	0218	M	M		5
6	M	M		250	42	2302	270	35	2349	360	18	0927	290	53	1530	M	M	M	220	36	2300	M	M		6
7	M	M		220	45	0233	250	37	0158	040	22	1232	290	50	1822	M	M	M	220	50	1828	M	M		7
8	M	M		360	65	0629	220	55	1242	290	52	2052	340	52	2232	M	M	M	290	51	0105	M	M		8
9	M	M		290	35	1133	M	M	M	290	45	0442	310	40	0012	M	M	M	250	52	2351	M	M		9
10	M	M		290	50	0417	360	33	1702	250	94	1100	290	72	1520	M	M	M	250	50	0040	M	M		10
11	M	M		290	49	2033	220	47	2047	220	70	2217	290	71	0304	M	M	M	220	48	1536	M	M		11
12	M	M		250	42	0254	M	M	M	220	66	1242	290	40	0140	290	52	1025	250	41	0652	M	M		12
13	M	M		360	35	2150	M	M	M	250	66	0535	290	48	1801	220	70	0615	110	26	1511	M	M		13
14	M	M		360	41	0200	M	M	M	220	58	0638	290	45	0145	290	56	2357	270	27	0350	M	M		14
15	M	M		270	26	1905	M	M	M	220	65	2337	220	45	1737	M	M	M	310	28	2236	M	M		15
16	M	M		290	37	0318	M	M	M	250	53	2050	250	60	1022	M	M	M	200	26	1115	M	M		16
17	M	M		310	37	0335	M	M	M	290	50	2348	200	39	1222	220	49	1105	160	41	1300	M	M		17
18	M	M		250	40	0808	220	50	1520	310	50	0332	340	38	2219	340	42	1452	160	50	1108	M	M		18
19	M	M		290	60	0918	220	41	2149	310	43	2045	110	50	2220	310	41	0222	090	68	1130	M	M		19
20	M	M		220	65	2323	220	36	0651	250	77	1925	130	56	0218	290	42	0800	250	43	1103	M	M		20
21	M	M		220	100	1512	290	46	1028	220	70	2114	200	30	0048	270	37	0345	290	48	0345	M	M		21
22	M	M		220	60	0649	220	58	1017	220	72	0521	040	16	0052	290	41	1721	040	18	1312	M	M		22
23	M	M		290	56	0851	340	44	0222	290	50	1836	340	22	1702	220	53	0947	160	30	1106	M	M		23
24	M	M		220	64	2151	250	52	1357	250	81	2208	290	40	0239	290	52	1155	220	42	0258	M	M		24
25	M	M		220	76	1120	290	44	0121	250	78	0821	220	82	1020	220	49	2302	090	32	1728	M	M		25
26	M	M		220	60	0447	220	33	1808	290	48	0617	M	69	0515	220	68	1952	290	35	1341	M	M		26
27	M	M		220	45	0633	250	51	0335	290	42	0736	M	M	M	220	75	0205	270	40	0110	M	M		27
28	M	M		220	51	1415	M	M	M	290	47	1923	M	M	M	220	50	0024	220	34	0411	M	M		28
29	M	M		220	73	2304	M	M	M	290	60	2129				220	41	2309	310	27	1826	M	M		29
30	M	M		220	77	1020	M	M	M	290	74	1520				220	55	2129	310	25	0008	M	M		30
31	M	M					250	62	1730	340	50	0451				220	70	0240				M	M		31
MONTH MAX				220	100	1512	220	86	1509	250	94	1100	220	82	1020	220	75	0205	090	68	1130				MAX
AVE					50			49			54			49			52			40					AVE

YEARLY MAX -- 220 100 MPH ON NOV 21 AT 1512 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1971-72

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		240	56	2210	180	17	1317	260	74	2042	220	33	0733	360	44	0421	250	36	2342	M	M		1
2	M	M		260	57	0530	290	19	1330	280	86	0934	340	33	1210	230	62	2329	260	42	0434	M	M		2
3	M	M		200	51	1056	230	37	0250	150	47	1035	290	60	1550	280	75	0932	280	32	0729	M	M		3
4	M	M		230	55	2035	280	15	2319	280	62	2325	290	40	0211	290	65	0425	210	40	0604	M	M		4
5	M	M		230	55	1410	280	55	1720	280	66	0658	280	37	1150	250	55	0532	200	64	2132	M	M		5
6	M	M		290	44	0312	230	60	0858	290	55	1350	040	20	1039	230	96	1721	190	50	1033	M	M		6
7	M	M		290	30	0416	160	34	1229	240	55	2047	330	32	0534	240	76	0156	260	37	0018	M	M		7
8	M	M		240	31	1104	280	40	2328	230	57	0508	240	32	2256	300	43	0605	190	45	2140	M	M		8
9	M	M		230	35	1241	320	43	0508	260	81	1636	230	35	0130	280	30	0427	200	45	0330	M	M		9
10	M	M		230	29	1140	210	38	1249	240	79	0728	020	14	2142	210	32	2148	190	60	2029	M	M		10
11	M	M		240	26	1350	220	31	1255	220	106	1220	300	36	2355	260	47	0304	190	57	2218	M	M		11
12	M	M		230	30	1001	200	50	1808	240	76	0251	280	56	0438	290	35	1126	210	67	0725	M	M		12
13	M	M		290	47	0729	240	41	0055	290	79	0540	230	60	1927	270	30	1044	200	42	0021	M	M		13
14	M	M		230	45	0622	230	35	2300	290	70	0630	240	46	0222	320	27	1805	120	20	0202	M	M		14
15	M	M		190	41	0356	320	27	0146	290	41	0020	270	40	2258	280	32	2321	320	27	1338	M	M		15
16	M	M		200	35	1215	300	42	0606	230	34	0832	230	62	1938	240	43	1614	200	54	2335	M	M		16
17	M	M		340	15	0012	340	31	0325	270	55	2312	320	62	1630	250	40	1400	210	71	0022	M	M		17
18	M	M		320	35	2349	300	35	2210	290	60	0452	290	56	0123	170	36	2154	190	51	1335	M	M		18
19	M	M		320	33	0035	270	47	1109	300	43	1316	280	42	1022	170	45	0040	210	36	0815	M	M		19
20	M	M		270	36	0129	300	57	0346	350	26	2352	260	36	1315	300	39	0803	350	30	2225	M	M		20
21	M	M		200	23	0015	230	45	0312	240	105	2328	210	36	2341	260	32	0243	270	35	1129	M	M		21
22	M	M		340	21	2118	210	66	2349	230	80	1245	230	48	1225	210	40	0242	260	54	0226	M	M		22
23	M	M		290	40	1638	230	80	1012	230	77	1150	240	54	0236	260	40	1701	290	25	0938	M	M		23
24	M	M		280	43	0640	220	65	1928	240	75	0608	230	66	1022	260	36	1053	230	26	1412	M	M		24
25	M	M		220	49	1210	230	75	0425	210	63	2008	330	41	1541	190	56	2227	200	37	1638	M	M		25
26	M	M		270	57	0920	200	61	0721	210	55	1245	240	55	1319	190	55	0301	330	55	0848	M	M		26
27	M	M		230	51	0121	230	47	0309	220	60	0130	290	43	1344	210	31	0658	330	31	0054	M	M		27
28	M	M		290	40	2030	220	39	0923	230	62	0452	230	48	1417	350	26	1820	260	25	1318	M	M		28
29	M	M		300	30	0038	240	50	1248	290	26	1237	230	76	0720	300	16	2241	190	35	1449	M	M		29
30	M	M		300	28	0150	280	55	1951	300	17	0232				280	36	2211	210	43	1214	M	M		30
31	M	M					290	32	2204	240	20	2355				340	45	1615				M	M		31
MONTH MAX				260	57	0530	230	80	1012	220	106	1220	230	76	0720	230	96	1721	210	71	0022				MAX
AVE					39			44			61			45			44			42					AVE

YEARLY MAX -- 220 106 MPH ON JAN 11 AT 1220 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1972-73

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		330	41	1424	290	61	1248	290	21	1259	350	30	0910	350	30	0438	090	34	2332	M	M		1
2	M	M		350	33	0039	240	63	1724	010	18	0505	280	20	2216	030	20	1421	040	32	1956	M	M		2
3	M	M		310	27	1824	220	54	1933	220	38	1943	M	21	1204	270	19	1907	350	37	1429	M	M		3
4	M	M		240	29	1525	250	79	1658	240	31	1319	290	35	0603	210	35	1952	010	30	1540	M	M		4
5	M	M		220	29	0450	220	48	0159	230	49	2150	290	30	0543	290	35	1243	350	27	1540	M	M		5
6	M	M		340	28	1008	230	56	2144	240	47	0107	230	48	2229	250	31	1405	300	48	1057	M	M		6
7	M	M		220	35	1135	220	64	0300	240	40	0430	240	51	0138	270	29	0654	140	60	1052	M	M		7
8	M	M		270	44	0312	220	60	0934	240	42	1036	180	14	1446	170	27	2113	360	47	2350	M	M		8
9	M	M		360	31	0529	240	31	1617	240	36	0037	290	25	2234	210	30	1144	350	49	0028	M	M		9
10	M	M		180	26	1300	240	46	1947	340	35	1335	240	40	2311	310	22	1845	300	36	1005	M	M		10
11	M	M		040	16	1534	230	49	0023	310	31	2107	230	34	0049	310	30	0354	050	15	0503	M	M		11
12	M	M		200	26	0424	240	47	1623	290	57	1827	280	41	1237	190	46	2344	310	20	0445	M	M		12
13	M	M		250	17	2159	240	50	0815	290	71	0645	280	20	2357	180	58	0527	220	40	2346	M	M		13
14	M	M		270	26	0637	330	32	1835	300	47	0103	290	26	1018	310	50	0132	200	50	1157	M	M		14
15	M	M		350	31	1717	300	36	1423	260	28	1958	030	19	1111	330	39	1247	340	34	2150	M	M		15
16	M	M		350	23	0036	280	36	1856	290	31	2240	050	16	1400	350	40	1300	290	45	1704	M	M		16
17	M	M		260	19	0040	290	38	2316	290	39	2321	010	15	0302	230	43	2227	300	57	0042	M	M		17
18	M	M		340	18	1718	330	51	0914	280	50	0437	290	26	2256	250	36	0011	190	40	1229	M	M		18
19	M	M		200	17	2128	300	60	1108	220	52	0322	300	33	1243	220	17	2243	320	60	1846	M	M		19
20	M	M		140	30	1247	330	45	0209	360	26	1639	290	37	1258	200	32	2326	300	55	0725	M	M		20
21	M	M		340	24	1519	280	45	1104	020	25	0136	220	20	0054	210	51	0510	290	22	0732	M	M		21
22	M	M		030	12	0310	280	50	2147	350	25	1905	140	51	0808	270	40	0614	330	41	1017	M	M		22
23	M	M		220	14	0720	320	44	0629	040	25	1326	170	21	0104	150	23	1529	250	21	1407	M	M		23
24	M	M		340	54	1843	240	70	0848	350	19	0133	310	25	0912	010	26	1130	240	25	1154	M	M		24
25	M	M		300	51	1505	320	39	0659	050	13	1400	280	38	0722	360	20	1647	300	35	1445	M	M		25
26	M	M		290	89	0726	290	49	1914	140	30	0745	280	27	0139	260	22	2009	330	27	2345	M	M		26
27	M	M		320	66	0116	220	38	2239	020	18	2102	250	25	2343	190	28	1100	250	33	2345	M	M		27
28	M	M		300	41	0444	210	28	0534	290	40	1556	260	24	0136	200	23	1416	230	57	1505	M	M		28
29	M	M		280	74	1726	160	37	0434	230	62	2254				200	20	1720	240	59	0504	M	M		29
30	M	M		290	66	2226	300	45	0636	240	75	0104				030	20	1500	M	M	M	M	M		30
31	M	M					290	40	0047	230	29	0049				290	36	2136				M	M		31
MONTH MAX				290	89	0726	250	79	1658	240	75	0104	240	51	0138	210	61	0510	140	60	1052				MAX
AVE					35			48			37			29			32			39				AVE

YEARLY MAX -- 290 89 MPH ON NOV 26 AT 0726 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1973-74

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		240	71	0138	220	70	2231	240	24	0149	240	41	1600	230	82	0250	210	55	2138	M	M		1
2	M	M		230	50	1247	210	70	0020	190	20	1100	360	45	0259	220	77	1030	210	50	0033	M	M		2
3	M	M		230	55	0733	310	31	2022	230	51	2153	270	50	1742	220	55	1342	350	40	0945	M	M		3
4	M	M		240	60	2311	290	34	2016	230	50	2133	240	59	1129	030	50	2225	300	35	1932	M	M		4
5	M	M		250	61	0019	310	43	0227	230	64	1626	230	45	0005	240	50	1320	290	51	0750	M	M		5
6	M	M		250	55	1210	290	35	1225	290	55	1128	290	26	2203	230	60	1805	240	52	0227	M	M		6
7	M	M		240	48	2357	300	51	2110	250	55	0728	340	30	2247	220	75	2042	290	41	0115	M	M		7
8	M	M		250	56	0423	290	48	0941	230	54	1620	320	35	1746	220	78	0200	260	34	1201	M	M		8
9	M	M		240	37	2255	290	37	1227	240	40	0027	290	45	1422	130	51	1729	170	53	1817	M	M		9
10	M	M		280	31	0705	290	58	1300	250	60	2115	270	41	0046	310	45	2340	220	43	0528	M	M		10
11	M	M		260	40	1923	240	80	1921	230	65	0042	290	35	1416	290	57	0155	330	55	1059	M	M		11
12	M	M		250	80	1952	290	97	0621	230	51	1008	230	55	0542	250	25	1625	310	52	0124	M	M		12
13	M	M		230	64	0049	250	55	2211	260	49	2031	290	23	0948	220	61	2227	350	42	1633	M	M		13
14	M	M		300	60	2035	300	45	1938	290	60	1846	040	17	0955	240	65	2122	300	30	1737	M	M		14
15	M	M		300	26	0900	290	50	0845	260	40	0903	290	43	2315	270	46	1430	330	36	1306	M	M		15
16	M	M		250	60	0847	320	47	0656	260	29	0016	210	40	1958	290	50	0408	260	30	1756	M	M		16
17	M	M		270	54	0140	290	45	0652	270	25	0452	220	40	0828	240	61	2350	360	20	0842	M	M		17
18	M	M		230	55	0722	050	30	1037	280	40	2026	290	45	1312	230	50	1555	160	24	2045	M	M		18
19	M	M		230	48	0036	020	24	1250	230	50	0724	250	42	1252	230	50	1514	210	55	1340	M	M		19
20	M	M		330	35	1944	290	45	1855	250	21	0532	010	39	1715	240	60	0217	300	42	2010	M	M		20
21	M	M		260	50	0400	240	55	2351	240	39	0157	300	43	1429	260	41	1300	290	35	1927	M	M		21
22	M	M		240	50	0709	240	70	0745	340	45	1251	240	60	1351	260	55	0604	350	30	0035	M	M		22
23	M	M		250	44	2253	020	25	2137	350	31	0502	300	50	0200	270	50	0104	240	35	0300	M	M		23
24	M	M		300	54	0418	020	35	0730	310	15	2145	330	33	1958	270	46	1007	220	45	0322	M	M		24
25	M	M		250	51	1840	280	55	1000	220	54	0855	310	35	0632	290	53	0700	240	18	0024	M	M		25
26	M	M		240	40	0143	280	30	1407	260	40	0013	220	46	2211	300	27	0011	230	55	2341	M	M		26
27	M	M		290	65	1522	270	85	1919	310	42	2014	230	83	1547	230	55	0558	220	65	0351	M	M		27
28	M	M		290	57	0100	240	78	1207	310	45	1918	240	55	0656	250	80	1110	230	32	0307	M	M		28
29	M	M		240	68	2144	270	89	0540	270	65	2005				290	70	0249	350	25	1655	M	M		29
30	M	M		220	57	0845	290	50	0346	320	58	1233				240	70	0018	020	16	0256	M	M		30
31	M	M					240	35	1603	260	51	1845				220	47	0237				M	M		31
MONTH MAX				250	80	1952	290	97	0621	230	65	0042	230	83	1547	230	82	0250	220	65	0351				MAX
AVE					53			52			45			43			56			40				AVE

YEARLY MAX -- 290 97 MPH ON DEC 12 AT 0621 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

CHAIRLIFT - ELEV. 11,880 FT.

WINTER 1974-75

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		280	31	0250	320	30	0159	170	22	1337	230	61	0752	290	40	0959	240	42	1249	M	M		1
2	M	M		230	26	0246	350	25	0603	010	40	1118	230	21	0015	250	49	1050	250	46	2004	M	M		2
3	M	M		160	17	0948	290	21	0257	300	37	0650	310	20	0718	340	39	0342	220	59	2156	M	M		3
4	M	M		010	20	0836	310	17	1048	320	49	2345	070	15	1225	220	60	1837	220	65	0557	M	M		4
5	M	M		020	15	0629	350	21	2353	300	50	0558	320	40	1319	220	75	0128	230	60	0100	M	M		5
6	M	M		040	22	2218	340	31	2326	230	70	0315	310	41	1345	240	55	0737	210	60	2308	M	M		6
7	M	M		060	16	0711	290	30	0345	240	56	0441	220	50	2151	230	44	2145	200	64	0011	M	M		7
8	M	M		200	28	2352	020	16	0712	200	65	1119	230	60	1246	210	50	0857	300	45	0145	M	M		8
9	M	M		320	28	2348	010	20	0411	340	31	1453	210	71	1935	340	30	1336	310	31	0838	M	M		9
10	M	M		350	50	2225	020	15	2008	330	40	1110	230	51	1511	220	34	0710	140	26	0040	M	M		10
11	M	M		310	45	0402	290	65	2351	290	55	1458	280	62	0311	200	24	1850	180	30	1258	M	M		11
12	M	M		300	57	0632	290	64	0029	330	45	0641	240	55	2338	280	20	1650	230	30	0225	M	M		12
13	M	M		290	78	0140	220	50	0604	280	60	1210	220	84	0523	300	26	0929	300	29	2304	M	M		13
14	M	M		310	55	0302	270	43	2304	260	61	1729	110	30	2050	120	32	2335	260	35	2333	M	M		14
15	M	M		300	40	0125	330	54	0405	290	42	1203	180	30	0008	120	27	0032	260	50	0752	M	M		15
16	M	M		350	29	0148	300	56	1727	230	47	1655	280	18	1143	200	40	2251	240	60	0417	M	M		16
17	M	M		290	24	2235	230	45	1218	290	50	1300	290	27	2309	280	37	1956	250	52	0855	M	M		17
18	M	M		240	75	1440	330	40	0427	280	75	1652	330	33	1346	280	45	1044	300	63	2248	M	M		18
19	M	M		320	46	0129	310	69	2101	280	45	1155	280	47	1500	260	52	0724	310	50	0318	M	M		19
20	M	M		260	43	2136	190	77	2329	230	76	1327	210	63	0616	240	55	0600	320	26	0808	M	M		20
21	M	M		250	30	1957	200	74	0040	250	41	0029	120	35	1922	210	65	2321	220	34	1404	M	M		21
22	M	M		230	36	0511	120	39	1550	320	31	2318	340	26	1927	210	73	0428	240	47	1346	M	M		22
23	M	M		350	37	1206	170	39	0028	280	46	2152	350	40	0151	280	70	1945	260	37	0028	M	M		23
24	M	M		290	34	0246	170	40	0002	300	79	1718	290	55	1453	290	76	0153	230	45	2348	M	M		24
25	M	M		240	61	1336	200	26	2217	290	90	0828	310	41	1208	190	40	1233	230	56	1739	M	M		25
26	M	M		270	45	1812	230	21	0237	230	85	1200	300	35	2010	190	47	0226	220	70	0906	M	M		26
27	M	M		250	47	1057	M	M	M	230	55	0803	270	73	0248	200	35	0015	330	67	2244	M	M		27
28	M	M		190	29	0838	M	M	M	270	70	1638	280	56	0808	330	31	1316	360	55	0047	M	M		28
29	M	M		360	25	1625	200	30	0137	230	62	0418				320	34	2344	330	30	0104	M	M		29
30	M	M		350	26	2251	300	20	0345	220	57	1206				280	44	1128	300	32	0916	M	M		30
31	M	M					M	M	M	220	49	1434				230	52	0549				M	M		31
MONTH MAX				290	78	0140	190	77	2329	290	90	0828	220	84	0523	290	76	0153	220	70	0906				MAX
AVE					37			39			54			44			45			47				AVE

YEARLY MAX -- 290 90 MPH ON JAN 25 AT 0828 HOURS

M = MISSING DATA

Mines Peak—Elevation 12,493 Feet

ailing Wind Direction and Mean Daily Windspeed

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1968-69
PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	N	9	NW	29	NW	49	W	33	E	12	NW	25	N	19	1
2	M	M	N	21	NW	33	NW	36	W	48	N	12	W	12	W*	14*	2
3	M	M	W	19	NW	54	NW	22	W	36	E	12	W	20	SW	12	3
4	M	M	W	22	NW	56	NW	27	W	17	E	18	NW	17	E	10	4
5	M	M	NW	16	W*	35*	NW	35	W	29	N	17	NW	13	E	10	5
6	M	M	NW	17	W	31	W	49	W	23	NW	17	SE	24	E*	22	6
7	M	M	NW	21	NW	31	SW	42	NW	21	E	24	W	40	M	M	7
8	M	M	NW	37	NW	36	W*	37	NW	23	NW	15	NW	31	M	21	8
9	M	M	NW	51	NW	21	W	31	W	32	NW	19	N	14	M	30	9
10	M	22	NW	44	W	27	W	34	W	40	E	5	W	9	M	18	10
11	M	10	NW	43	W*	32*	W	32	NW	30	N	14	E	10	NW	22	11
12	M	20	W	39	NW	59	W	29	W	13	NW	26	N	8	NW	23	12
13	M	19	W	16	NW	38	W	27	N	11	W	15	NW	8	NW	M	13
14	M	22	W	12	W	29	NW	20	NW	16	E	10	W	16	NW	M	14
15	M	17	NW	29	W	28	NW	27	NW	21	N	18	E	14	N	M	15
16	N*	20	NW	43	W	23	W	22	NW	12	NW	20	E	9	N	M	16
17	NW	27	NW	44	N	17	W	33	NW	21	NW	25	NW	18	NW	M	17
18	NW*	28	NW	41	N	31	NW	24	E	19	NW	34	NW	11	W	M	18
19	NW	25	N	25	E	19	NW	33	E	19	NW	40	W	14	W	M	19
20	W	18	NW	33	E	15	NW	28	NW	24	W	19	NW	36	W	16*	20
21	NW	35	NW	18	N	22	W	25	NW	18	W	23	W	19	W	13	21
22	NW	43	NW	39	NW	52	NW	30	W	16	E	15	SE	12	W	18	22
23	NW	45	NW	25	NW	38	W	30	NW	13	W	25	SW	10	W	15	23
24	NW	23	W	22	NW	35	W	28	W	26	N	16	SW	16	NW	13	24
25	NW	17	NW	24	W	37	W	25	W	31	NW	42	NW	33	NW	11	25
26	NW	42	E	10	W	12	W	28	W	25	NW	37	NW	33	W	11	26
27	NW	41	N	14	NW	28	W	17	NW	24	NW	38	NW	28	W*	12*	27
28	NW	20	E	7	NW	40	S	16	SW	16	W	39	W	17	E	17	28
29	W*	13*	N	21	W	34	W*	19			NW	42	W	21	W	10	29
30	W	18	N	15	W	53	W	28			NW	33	W	20	W	24	30
31	W	20			NW	60	W	41			W	36			NW	21	31
MONTHLY MAX	NW	45	NW	51	NW	60	NW	49	W	48	NW	42	W	40	M	30	MAX
AVE		25		26		34		30		23		23		19		17	AVE

YEARLY MAX -- NW 60 MPH ON DEC 31

VAR - VARIABLE DIRECTION
M = MISSING DATA
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1969-70

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	M	M	N	8	N	18	NW	43	W	20	NW	35	NW	15	1
2	M	M	M	M	N°	10	N	29	NW	45	W	32	W	32	N°	21	2
3	M	M	M	M	SE	14	NW	43	NW	47	NW	23	NW	12	M	14	3
4	M	M	M	M	N	22	NW	23	NW	41	NW	26	NW	33	W	11	4
5	M	M	N°	22	N	8	N	24	NW	40	NW	15	NW	43	SW	8	5
6	M	M	N°	22	N	29	NW	33	NW	37	N	31	NW	13	W	10	6
7	M	M	S°	16	N°	29°	W	49	N	26	N	31	NW	28	N	16	7
8	M	M	M	19	M	M	W°	41	N	22	NW	27	NW	34	NW	33	8
9	M	M	W	17	N	23	M	45	N°	21°	W	22	N	10	NW	34	9
10	M	M	NW	31	N	38	NW	43	N	26	SE	12	NW	34	W	27	10
11	M	M	NW	39	NW	43	NW	37	N	23	N	13	NW	31	SW	19	11
12	M	M	NW	44	NW	44	NW	30	NW	34	N	29	NW	36	W	15	12
13	M	M	W	51	NW	39	NW	33	NW	31	NW	43	NW	24	M	M	13
14	M	M	W	33	NW	33	NW	33	NW	23	NW	36	SE	26	M	M	14
15	M	M	W	25	NW	29	N	21	N	31	E	12	W	23	M	M	15
16	M	M	SW	28	NW	26	W	29	NW	49	N	21	E	14	M	M	16
17	M	M	M	29	NW	29	NW	35	W	34	N	24	SE	23	M	M	17
18	M	M	N	35	NW	18	NW	38	NW	29	N	21	NW	36	M	M	18
19	M	M	N°	40	NW	26	W	55	N	20	N	19	NW	36	M	M	19
20	M	M	N	28	NW	51	NW	43	N	19	N	15	NW	38	M	M	20
21	M	M	NW	25	W	38	W	46	N°	14	NW	30	SE°	21	M	M	21
22	M	M	N	16	W	52	W	50	SE	18	NW	40	W	24	M	M	22
23	M	M	N	13	W	37	W	44	N	10	NW	55	NW	25	M	M	23
24	M	M	NW	26	W	39	W	38	SE	7	NW	48	NW	29	M	M	24
25	M	M	NW	19	NW	31	W	37	N	25	NW	32	W	30	M	M	25
26	M	M	NW	23	N	24	W	29	N	38	N	16	W	22	M	M	26
27	M	M	N	9	E	11	W	36	NW	25	E	19	S	17	M	M	27
28	M	M	N	5	SE	13	NW	35	W	19	N	21	N	14	M	M	28
29	M	M	N	15	N	21	NW	43			E	15	N	14	M	M	29
30	M	M	N	18	N	21	NW	21			E	34	N	12	M	M	30
31	M	M			N	24	NW	21			SE	11			M	M	31
MONTHLY MAX			W	51	W	52	W	55	NW	49	NW	55	NW	43	NW	34	MAX
AVE		°°		25		28		36		29		26		26		°°	AVE

YEARLY MAX -- W 55 MPH ON JAN 19

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1970-71

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	M	M	N	27°	W	24	NW	13	E	21	W	30	NW	17	1
2	M	M	M	M	N	32	E	32	NW	20	NW°	20	W	32	W	14	2
3	M	M	M	M	N	40	E	43	N	17	NW	43	NW	27	SW	10	3
4	M	M	M	M	N	29	NW	21	NW	38	W	20	NW	20	N	16	4
5	M	M	M	M	NW	33	NW	25	NW	43	NW	22°	NW	25	NW	21	5
6	M	M	M	M	NW	28	NW	25	NW	36	W	43	NW	11	E	12	6
7	M	M	M	M	W	29	NW	27	NW	44	W	49	W	23	E	13	7
8	M	M	M	M	W	30	NW	59	NW	46	NW	22	NW	18	W	11	8
9	M	M	M	M	SW	16	W	57	NW	34	W	35	W	14	NW	29	9
10	M	M	M	M	N	24	W	56	NW	53	W	40	W	24	N	16	10
11	M	M	M	M	NW	30	W	46	NW	49	NW	33	SW	25	E	10°	11
12	M	M	M	19°	NW	34	W°	35°	NW	30	W	27	W	26	N	12°	12
13	M	M	M	10	W	23	W	29	NW	42	W	20	E	12	NW	12	13
14	M	M	M	20°	W	19	W	33	NW	29	NW	44	W	15	NW	20	14
15	M	M	M	24	NW	30	W	49	W	32	W	37	NW	12	M	20	15
16	M	M	M	30	W	35	W	40	W	32	W	28	SW	14	M	21	16
17	M	M	NW	30	SW	25	W	37	SW	16	SW	27	S	13	M	16	17
18	M	M	W	22	W	20	NW	33	NW	24	NW	38	SE	20	M	13	18
19	M	M	NW	40	W	25	N	34	NW°	27	NW	40	E	24	W°	29	19
20	M	M	W	38	W	16	W	48	M	37	W	37	W	27	W	20	20
21	M	M	W	44	W	29	W	34	M	9	W	30	NW°	21°	SE	17	21
22	M	M	W	32	W	43	W	36	M	13	W	31	E	5	N	16	22
23	M	M	NW	35	NW	39	NW	37	NW°	19	W	27	E	11	N	22	23
24	M	M	W	26	W	51	NW	44	N	29	W	32	W	18	NW	34	24
25	M	M	W	36	NW	42	W	45	NW	38	W	31	E	18	W	16	25
26	M	M	W	20	W	28	NW	42	NW	49	W	33	W	16	E	16	26
27	M	M	W	21	W	34	NW	30	NW	30	W	28	W	29	SW	15	27
28	M	M	W	25	NW	34	NW	38	NW	13	W	30	W	15	SE	16	28
29	M	M	W	27	W	40	NW	55			W	32	NW	27	M	17	29
30	M	M	W	44	NW	55	NW	63			W	27	NW	22	W	17	30
31	M	M			N	50	NW	27			NW	32			M	16	31
MONTHLY MAX			W	44	NW	55	NW	63	NW	53	W	49	W	38	NW	34	MAX
AVE		°°		°°		32		39		31		32		20		17	AVE

YEARLY MAX -- NW 63 MPH ON JAN 30

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1971-72

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	M	M	NW	36	E	13	W	53	W	16	W	36	NW	37	NW	37	1
2	M	M	W	40	NW	13	W*	56	NW	26	W	39	NW	38	NW	26	2
3	M	M	W	48	NW	17	E*	40	W	51	W	52	NW	34	NW	25	3
4	M	M	W	42	NW	11	NW	43	W	36	W	45	W	33	NW	19	4
5	M	M	W	34	NW	35	W	61	W	32	W	52	NW	36	E	11	5
6	N	6*	W	33	W	25	W	57	NW	20	W*	62	W	36	E	11*	6
7	N	11*	W	19	E	21	W	32	NW	28	W	45	NW	29	NW	M	7
8	N	15	NW	24	W	16	W	42	NW	23	W	34	W	20	NW	M	8
9	N	15	W	23	NW	28	W	67	W	20	W	23	W	22	E	M	9
10	NW	16	W	19	W	21	W	60	E	M	W	24	W	30	NW	13	10
11	W	18*	W	17	W	13	W	70	NW	24*	W	24	W	30	N	14	11
12	NW	27	W	13	W	24	W	64	NW	41	W	29	W	29	NW	30	12
13	NW	30	NW	26	E	11	W	64	W	42	W	25	SW	15	N	26	13
14	W	M	SW	16	W	26	W	56	NW	35	NW	28	E	15	NW	19	14
15	SE	20	SE	24	W	23	NW	48	W	39	NW	29	N	24	NW	14	15
16	SE	31	SE	16	NW	39	W	34	W	52	NW	41	SW	17	M	11	16
17	SE	33	E	4	NW	25	NW	39	NW	56	W	34	W	23	W*	14	17
18	NW	25	SE	14	W	30	NW	50*	W	36	W	25	S	19	SW	14	18
19	NW	19	NW	31	NW	51	NW	39	W	31	W	22	SE	22	S	26	19
20	NW	11	NW	23	NW	63	NW	30	W	30	NW	25	NW	15	E	22	20
21	NW*	11	N	13	W	39	NW	46	SW	16	W	32	NW	30	N	17	21
22	NW	10	N	14	W	43	W	M	W	28	W	16	W	36	NW	15	22
23	NW	16	NW	33	W	48	W	40*	W	28	S	19	NW	20	NW*	14	23
24	SW	17	NW	34	W	37	W	38	W	31	NW	28	W	16	W	13	24
25	SW	20	W	28	W	42*	W	35	NW	25	W	33	SW	17	W	13	25
26	NW	28	NW	40	W	21*	SW	23	W	41	W	25	NW	34	E*	12	26
27	SW	26	NW	32	W	26	W	31	W	49	W	13	NW	26	M	8	27
28	SE	29*	NW	27	W	21	W	40	W	41	E	23	NW	29	M	19	28
29	SE	25*	NW	24	W	30	W	31	SW	36	NW	15	NW	22	M	12	29
30	W	39	NW	12	W	40	NW	23			NW	36	NW	24	M	M	30
31	W	15			NW	38	NW	19			NW	40			M	M	31
MONTHLY MAX	W	39	W	48	NW	63	W	70	NW	56	W	62	NW	38	NW	37	MAX
AVE		20		25		29		44		33		31		26		17	AVE

YEARLY MAX -- W 70 MPH ON JAN 11

VAR - VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1972-73

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	NW	18	N	30	NW	54	N	16	N	22	NW	19	E	23	M	11	1
2	NW	20	N	19	NW	51	NW	22	NW	24	N	13	E	19	NW*	28	2
3	N	22	N	17	W	33	W	16	NW	18	E	15	N	19	M	M	3
4	W	16	W	15	W	22	W	14	NW	28	SE	17	N	18	M	M	4
5	NW	13	NW	19	NW	23	NW	28	NW	24	NW	28	W	22	M	M	5
6	N	10	N	22	W	29	W	20	W	20	NW	27	NW	27	M	M	6
7	E	11	W	23	W	26	NW	24	NW	25	N	21	E	25	M	M	7
8	NW	13	N	20	SW	18	W	28	N	4	SE	20	NW	32	M	M	8
9	W	32	N	28	W	18	NW	21	N	15	S	10	NW	42	M	M	9
10	W	31	NW	20	W	28	NW	29	NW	32	N	18	NW	31	M	M	10
11	W*	20	N	10	W	14	NW	30	W	13	NW	20	W	9	M	M	11
12	NW	14	E	20	W	30	NW	44	NW	32	SW	17	NW	16	M	M	12
13	NW	26	N	15	W	21	NW	49	N	16	NW	28	SW	17	M	M	13
14	SW	16	W	20	NW	31	NW	20	NW	21	NW	16	SW	21	M	M	14
15	NW*	33	NW	24	NW	36	NW	19	NW	13	NW	16	NW	18	M	M	15
16	NW*	43	W	16	NW	28	NW	31	NW	13	NW	19	NW	28	M	M	16
17	NW	31	SE	11	NW	30	NW	33	N	11	W	13	W	21	M	M	17
18	W	11	N	15	NW	28	NW	33	NW	19	W	9	SE	17	M	M	18
19	SE	15	N	14	NW	42	W	21	NW	29	N	8	NW	51	M	M	19
20	E*	22*	E	32	NW	36	N	16	NW	25	SE	15	NW	35	M	M	20
21	M	M	N	18	NW	35	N	25	SE	9	S	26	NW	18	M	M	21
22	M	M	N	11	NW	30	N	17*	E	24	NW	27	NW	28	M	M	22
23	M	22*	SW	8	NW	36	N	21	N	17	E	16	W	13	M	M	23
24	M	28	NW	35	W	31	N	10	NW	15	N	14	W	7	M	M	24
25	M	31	NW	44	NW	34	NW*	11*	NW	27	N	16	NW	21	M	M	25
26	M	27*	NW	67	NW	41	E	14	NW	22	NW	18	N	19	M	M	26
27	SE	12	NW	32	W	25	N	12	NW	17	E	19	N	25	M	M	27
28	NW	26	NW	41	W	12	NW	29	NW	12	SE	14	W	31	M	M	28
29	W	28	NW	47	N	22	NW	38			SE	19	SW	25	M	M	29
30	E	28*	NW	61	N	42	W	32			N	12	E	18	M	M	30
31	E	17			N	16	N	10			N	31			M	M	31
MONTHLY MAX	NW	43	NW	67	NW	54	NW	49	NW	32	N	31	NW	51	NW	28	MAX
AVE		22		25		30		24		20		18		23		**	AVE

YEARLY MAX -- NW 67 MPH ON NOV 26

VAR - VARIABLE DIRECTION
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1973-74

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	NW	16	W	33	W	25	W	15	W	35	W	33	W	36	NW	34	1
2	W	21	SW	26	E	25	M	11	NW	40	W	39	NW	24	W	37	2
3	M	16	SW	28	N	21	W	26	NW	43	NW	23	N	31	W	22	3
4	M	11	W	27	NW	35	W	29	W	48	NW	45	NW	29	NW	11	4
5	NW	21	W	39	NW	34	W	28	N	14	NW	38	NW	45	F	10	5
6	W	27	M	45	NW	29	W	44	NW	14	W	43	W	32	NW	21	6
7	W	19	NW	41	NW	41	W	38	N	20	W	28	NW	41	NW	34	7
8	SE	16	NW	44	NW	36	M	29	NW	36	SW	22	NW	35	NW°	33	8
9	SE°	12	M	25	NW	38	M	23	NW	38	F	29	SW	27	M	33	9
10	E	11	NW	30	NW	46	M	39	NW	35	E	23	N	23	M	39	10
11	NW	25	NW	30	NW	42	M	40	NW	38	N	36	NW	51	M	33	11
12	NW	47	W	33	NW	47	NW	39	W	35	NW	20	NW	26	M	33	12
13	N	32	W	32	W	32	NW	40	NW	24	W	32	N	25	W°	35	13
14	NW	18	NW	38	NW	42	NW	47	N	19	W	34	NW	28	W	30	14
15	N	14	NW	31	NW	44	NW	42	M	33	NW	45	NW	30	SW	38	15
16	NW	23	M	34	NW	45	NW	28	M	26	NW	43	NW	20	SW°	23	16
17	NW	11	NW	31	NW	35	NW	22	M	22	NW	50	N	20	SW°	17	17
18	NW	21	W	25	E	13	NW	23	N	30	W	28	W	13	SE	17	18
19	N	12	E	19	N	15	NW	38	W	26	NW	30	SE	19	S	39	19
20	W	18	N	28	NW	40	NW	22	N	18	NW	34	NW	31	W	27	20
21	W	21	W	26	NW	34	W	18	NW	26	W	35	NW	31	W°	35°	21
22	M	17	W	23	W	27	NW	36	W	32	W	35	NW	20	W°	19°	22
23	W	34	NW	18	N	15	N	22	NW	41	NW	40	W	17	M	M	23
24	NW	37	N	25	N	28	NW	24	N	30	NW	40	W	18	M	M	24
25	W	23	W	24	NW	46	NW	28	NW	26	NW	40	NW	13	M	M	25
26	NW	19	W	16	NW	32	NW	28	W	33	W	20	SW	23	M	M	26
27	NW	38	NW	54	W	48	N	30	W	40	W	27	W	28	M	M	27
28	NW	24	NW	41	NW	61	NW	42	W	40	NW	46	SE°	11	M	M	28
29	W	22	W	36	NW	54	NW	60			NW	51	NW°	12	M	M	29
30	N	26	W	28	NW	33	NW	62			W	33	N	13	M	M	30
31	W	42			NW	27	NW	50			NW	29			M	M	31
MONTHLY MAX	NW	47	NW	54	NW	61	NW	62	W	48	NW	51	NW	51	M	39	MAX
AVE		22		31		35		33		31		35		26		28	AVE

YEARLY MAX -- NW 62 MPH ON JAN 30

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1974-75

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

DAY	OCT DIR	OCT SPD	NOV DIR	NOV SPD	DEC DIR	DEC SPD	JAN DIR	JAN SPD	FEB DIR	FEB SPD	MAR DIR	MAR SPD	APR DIR	APR SPD	MAY DIR	MAY SPD	DAY
1	NW	23	NW	13	NW	24	E	17	NW	30	NW	38	N	19	NW	19	1
2	NW	19	E°	12	NW	20	N	29	NW	15	NW	31	NW	47	NW	25	2
3	NW	19	E	10°	NW	22	NW	35	N	15	NW	31	W	32	NW	30	3
4	W	30	N	M	NW	18	NW	37	NW	7	NW	35	W	26	SW	17	4
5	W	23	E	9	N	15	NW	44	N	26	W	28	W	22	SW	17	5
6	NW	21	N	18	N	25	W	38	N	37	NW	35	SE	31	NW	36	6
7	NW	22	NW	16	E	18	NW	44	NW	40	NW	26	NW	34	NW	31	7
8	N	15	N	17	N	13	W	30	W	35	W	23	NW	37	W	13	8
9	W	14	NW	19	N	17	N	21	W°	38	N	14	NW	21	W	9	9
10	W	16	NW	32	N	10	NW	34	NW	30	W	15	E	24	W	17	10
11	E	14	NW	44	NW	37	NW	50	NW	44	N	13	E	26	NW	16	11
12	E	12	NW	51	NW	46	N	45°	NW	43	NW	15	E	10	N	24	12
13	N	7	NW	58	NW	33	NW	49	W	35	N	21	N	21	N	26	13
14	NW	15	NW	51	NW	42	NW	53	E	19	NW	18	NW	25	N	14°	14
15	N	25	NW	35	NW	40	NW	31	SE	13	F	13	W	25	W	12	15
16	N	17	NW	26	NW	45	NW	38	N	17	W	20	W	23	W	10	16
17	N	8	NW	21	NW	34	NW	39	N	22	N	26	W	20	N	14	17
18	W	6	W	42	NW	39	NW	52	N	30	NW	41	NW	35	NW	19	18
19	NW	14	NW	38	NW	43	NW	42	NW	39	NW	31	NW	29	W	24	19
20	M	9	NW°	44	NW	45	NW	47	NW	40	W	34	NW	17	SE	30	20
21	W	15	NW	29	NW	38	E	23	NW	23	W	26	SE	13	SE	36	21
22	SE	14	W	14	NW	32	N	27	N	21	W	35	W	22	SE	19	22
23	NW	10	NW	29	E°	28	NW	38	N	26	NW	51	M	18	NW	25	23
24	N	13	NW	28	N	25	NW	67	NW	40	NW	52	NW	21	NW	23	24
25	W	6	W	32	N	19	NW	71	NW	30	SW	23	SW	26	W	22	25
26	NW	13	NW	37	N	12	W	42	NW	35	E	23	S	29	W	17	26
27	E	12	NW	32	NW	23	W	23	NW	46	N	18	NW	45	N	13°	27
28	E	12	E	18	W	13	NW	31	NW	41	N	27	NW	46	E	18°	28
29	E	24	N	22	W	16	W	32			N	33	NW	25	F	M	29
30	NW	13	N	23	N	16	W	22			NW	38	NW	20	N°	16°	30
31	NW	24			N	13	W	22			NW	25			NW	22	31
MONTHLY MAX	W	30	NW	58	NW	46	NW	71	NW	46	NW	52	NW	47	NW	36	MAX
AVE		16		28		26		38		30		28		26		20	AVE

YEARLY MAX -- NW 71 MPH ON JAN 25

VAR = VARIABLE DIRECTION
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

M = MISSING DATA
°° = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1975-76

PREVAILING WIND DIRECTION AND MEAN DAILY WIND SPEED - MPH

	OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		
DAY	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DAY
1	M	M	E	9	NW	45	N	15	NW	43	W	27	W	21	NW*	22*	1
2	M	M	N	21	NW	42	N	23	NW	49	SW	20*	W	25	NW	21	2
3	M	M	N	25	NW	18	NW	34	NW	34	SE	17	W	18	VAR	11	3
4	M	M	N	8	NW	24	NW	39	SW	27	E*	23	SW	11	W	23	4
5	M	M	N	11	NW	29	W	37	W	21	NW	31	E*	23*	NW	22	5
6	M	M	NW	32	NW	41	NW	26	NW	21	N	12	M	M	M	15	6
7	M	M	W	27	NW	41	NW	34	NW	44	SW	9	NW	27	M	9	7
8	M	M	W	16	NW	38	NW	35	NW	42	NW	17	SE	14	SE	14	8
9	M	M	NW	26	NW	25	W	31	W	28	NW	35	W	25	N	17	9
10	M	M	W	35	NW	38	NW	32	N	31	NW	21	NW	27	*	11	10
11	M	M	NW	57	NW	21	W	33	NW	26	NW	22	SW	12	NW	33	11
12	M	M	NW	36	W	26	W	34	NW	36	NW	23	W	21	NW	40	12
13	M	M	NW	26	W	13	NW	39	NW	21	NW	37	SW	18	N	31	13
14	M	M	NW	23	N	17	NW	49	NW	27	NW	30	W	17	N	20	14
15	M	M	NW	23	NW	52	NW	53	NW	20	NW	35	W	16	N	13	15
16	M	M	W	25	W	40	NW	35	NW	35	NW	42	N	25	NW	12	16
17	N	18	W	17	NW	38	NW	26	NW	44	NW	31	E	17	NW	23	17
18	NW	18	SE	19	N	18	NW	28	W	47	W	35	NW	14	NW	15	18
19	NW	17	N	22	N	17	NW	20	W	24	W	39	N	18	N	18	19
20	NW	27	N	22	NW	10	NW	26	E	23	NW	45	NW	32	N	11	20
21	NW	25	E	12	N	16	NW	19	N	23	NW	48	NW	39	E*	12*	21
22	W	22	N	22	N	13	NW	34	NW	31	W	34	W	22	M	21*	22
23	E	15	NW	37	N	14	NW	36	W	32	W	38	NW	29	M	25	23
24	NW	18	NW	42	N	18	NW	25	NW	31	W	37	NW	32	NW	19	24
25	NW	39	N	29	N	19	NW	27	NW	35	W	28	SE	20	NW	22	25
26	W	38	NW	39	NW	22	NW	38	NW	31	NW	27	VAR	22	N	12	26
27	W	25	W	21	NW	46	N	28	NW	22	W	20	SE	15	W	10	27
28	W	26	W	20	N	16	N*	22	W	33	VAR	13	SW	12	NW	21	28
29	W	25	W	22	N	21	NW	27	W	32	N	9	W	13	VAR	9	29
30	W	19	NW*	64	W	16	NW	44			NW	29	N	14	VAR*	13*	30
31	E	16			E	14	N	28			NW	19			NW	18	31
MONTHLY MAX	NW	39	NW	64	NW	52	NW	53	NW	49	NW	48	NW	39	NW	40	MAX
AVE		**		26		26		32		31		28		21		18	AVE

YEARLY MAX -- NW 64 MPH ON NOV 30

VAR = VARIABLE DIRECTION
M = MISSING DATA
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY
** = MORE THAN 240 HOURS OF MISSING DATA FOR MONTH

Maximum Hourly Winds

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1968-69

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		270	14	02	310	42	06	300	64G	06	280	50	04	230	21	03	310	41	09	280	30	01	1
2	M	M		330	31	07	310	49G	24	310	55	19	290	65	15	340	19	16	290	19	05	100	26	15*	2
3	M	M		310	23	02	300	81G	19	320	29	01	300	50	01	110	21	24	330	35	21	100	21	20	3
4	M	M		310	32	22	310	75G	11	310	34	13	260	27	21	100	24	01	330	28	02	100	20	19	4
5	M	M		340	22	06	280	45	06*	300	47	09	290	39	22	330	25	19	320	19	05	090	21	16	5
6	M	M		330	22	16	310	40	23	260	66	14	270	32	03	090	30	16	150	40G	22	090	42G	12*	6
7	M	M		310	35	06	290	45	22	240	60	17	310	37	15	090	40	10	290	56G	10	M	M		7
8	M	M		310	45	13	300	44	01	240	70G	01*	280	30	19	300	30	24	310	55	04	M	M		8
9	M	M		300	75G	18	300	37	03	230	39	24	300	45	24	300	35	01	340	25	07	M	M		9
10	M	M		350	53	09	280	34	23	240	45G	08	280	54	21	100	11	12	290	19	07	M	M		10
11	M	M		300	50	09	270	45G	05*	260	45	21	300	47	08	320	30	24	100	21	12	300	35	05	11
12	M	M		270	50	12	300	69	18	270	49	03	280	20	06	300	39	03	340	20	17	320	35	16	12
13	M	M		290	35	01	310	65G	01	270	36	07	210	19	03	290	32	02	280	19	23	M	M		13
14	M	M		300	19	15	300	47	01	310	30	05	290	28	20	090	16	11	100	31	24	M	M		14
15	M	M		300	47G	24	280	36	05	280	35	14	300	40	03	340	27	16	100	30	01	M	M		15
16	320	30	17*	300	55G	21	290	35	03	270	35	08	330	25	24	340	24	18	100	21	06	M	M		16
17	300	35	15	300	50	08	260	25	01	280	43	20	300	26	20	300	35	04	330	27	18	M	M		17
18	300	34	15*	300	61	05	300	45	24	290	41	03	300	30	02	300	50	10	320	25	01	M	M		18
19	300	48	05	310	43	03	310	41	01	280	44	08	110	30	02	300	55G	09	280	37	20	M	M		19
20	290	34	24	310	49	09	100	27	15	270	38	17	310	33	15	310	29	01	290	51	03	230	25	15*	20
21	280	51G	05	330	30	01	340	40	24	280	36	24	320	28	10	300	40	11	280	35	06	290	25	02	21
22	300	56	23	310	60	16	300	61	22	300	40	13	260	30	03	300	30	06	090	35	14	300	30	11	22
23	300	60	03	300	44	13	290	55G	02	310	42	18	290	21	02	280	36	07	160	15	12	320	34	15	23
24	330	35	01	250	30	22	310	48	01	290	39	04	250	35	20	310	26	23	230	21	11	300	20	02	24
25	330	21	08	300	34	18	270	69G	05	260	36	24	260	42	08	310	50	12	320	47	07	300	20	23	25
26	300	56	14	330	24	01	260	27	01	240	40	19	260	40	04	310	56	08	320	43	20	290	20	01	26
27	300	50	07	360	20	11	310	43	12	260	39	01	300	36	02	300	61	16	320	55	06	270	20	21*	27
28	330	36	02	090	19	01	300	55G	21	210	24	11	260	25	02	300	50	01	300	31	05	300	29	05	28
29	290	22	13*	340	27	11	300	50	02	280	41	20*				300	51	10	300	34	07	310	23	18	29
30	300	29	04	340	29	08	320	66G	20	260	34	24				300	45	04	280	27	03	290	35	10	30
31	310	39	03				290	75G	05	290	66	12				290	55	04				320	39	01	31
MONTHLY MAX	300	60	03	300	75G	18	300	81G	19	240	70G	01	290	65	15	300	61	16	290	56G	10	090	42G	12	MAX
AVE		40			38			49			43			35			35			32			28		AVE

YEARLY MAX -- 81G MPH ON DEC 3 AT 1900 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR - VARIABLE DIRECTION
HR - WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1969-70

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		090	26	01	010	32	22	330	65	09	280	31	02	300	65	21	330	27	24	1
2	M	M		M	M		010	15	16*	340	43	19	320	64	17	310	47	19	290	50	01	330	29	05*	2
3	M	M		M	M		010	19	01	340	70G	11	320	62	02	310	37	16	320	23	18	M	M		3
4	M	M		M	M		340	36	15	300	42	01	300	48G	04	300	45	08	300	46	20	290	16	09	4
5	M	M		330	31	01*	010	23	24	330	38	15	310	47	06	290	34	01	310	52	10	300	15	03	5
6	M	M		350	25	04*	360	33	07	320	42	06	320	46	06	350	49	17	330	29	01	240	15	10	6
7	M	M		280	35	23*	330	36	16*	300	57	07	330	37	07	340	35	01	300	39	23	280	35	24	7
8	M	M		M	M		M	M		270	52	01*	340	35	14	310	40	06	300	45	11	320	42	18	8
9	M	M		290	30	24	330	30	08	M	M		340	24	20*	290	41	08	310	25	24	320	52	03	9
10	M	M		310	40	09	340	59	11	310	64G	05	330	38	19	130	26	13	290	45	18	310	39	05	10
11	M	M		310	48	22	320	51	11	320	49	03	320	42	24	330	20	18	340	53	22	260	41	02	11
12	M	M		310	61G	18	320	52	01	310	41	03	320	46	04	310	52	24	330	45	01	280	31	09	12
13	M	M		290	56	05	330	54	01	310	47	08	300	40	17	320	61	03	110	37	21	M	M		13
14	M	M		260	56	02	330	39	04	320	40	11	300	35	08	320	48	05	160	40	12	M	M		14
15	M	M		250	42	24	320	36	06	320	31	01	320	55	24	300	29	06	280	43	11	M	M		15
16	M	M		220	37	07	320	39	05	300	40	07	310	65	03	310	40	24	140	20	15	M	M		16
17	M	M		M	M		320	42	05	300	55	08	330	45	22	310	37	01	130	41	12	M	M		17
18	M	M		010	41	08	310	28	06	300	46	12	320	46	05	340	42	06	330	59	22	M	M		18
19	M	M		320	63	18*	290	40	21	290	70	15	350	30	17	350	25	04	320	61	02	M	M		19
20	M	M		350	39	05	300	68	12	310	58	08	340	31	02	320	26	05	330	53	07	M	M		20
21	M	M		320	34	15	300	48	01	290	57	04	350	22	08*	310	43	14	270	34	01*	M	M		21
22	M	M		350	26	01	310	70	07	280	70	17	110	40	20	310	57	07	300	36	05	M	M		22
23	M	M		340	26	23	290	56	02	290	63	03	280	15	05	310	74	15	300	35	20	M	M		23
24	M	M		310	37	14	320	54	20	250	54	17	120	15	10	300	71	10	290	40	24	M	M		24
25	M	M		330	34	23	330	45	01	270	57G	02	330	41	22	350	51	09	300	51	03	M	M		25
26	M	M		320	44	02	290	38	08	250	46	24	320	51	23	340	29	01	270	29	02	M	M		26
27	M	M		360	13	20	100	22	08	260	53	05	310	42	05	340	35	24	150	30	17	M	M		27
28	M	M		360	11	09	130	19	02	300	53	13	310	46	04	340	34	03	260	21	08	M	M		28
29	M	M		350	28	15	360	30	18	320	58	10				090	32	24	290	20	02	M	M		29
30	M	M		360	26	06	010	31	15	310	47	01				090	42	04	350	19	04	M	M		30
31	M	M					010	31	11	310	43	24				110	25	17				M	M		31
MONTHLY MAX				320	63	18	310	70	07	340	70G	11	330	65	09	310	74	15	300	65	21	320	52	03	MAX
AVE					37			39			51			42			41			40			31		AVE

YEARLY MAX -- 74 MPH ON MAR 23 AT 1500 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1970-71

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		M	M		260	45	03*	270	35	04	290	29	02	090	37	22	290	43	02	300	32	08	1
2	M	M		M	M		250	47G	15	100	56	24	300	26	10	290	35	16*	290	40	05	300	21	06	2
3	M	M		M	M		300	62G	06	100	57	03	240	30	03	290	59	07	290	45	05	290	16	02	3
4	M	M		M	M		260	40	01	300	40	20	290	65	24	270	31	01	290	35	23	330	26	21	4
5	M	M		M	M		300	42	19	310	35	01	290	62	02	310	35	15*	300	37	04	320	29	14	5
6	M	M		M	M		300	40	24	320	32	07	300	52	15	290	55	17	260	20	24	090	24	16	6
7	M	M		M	M		290	44	03	300	35	24	310	62	15	290	60	06	290	35	24	110	24	17	7
8	M	M		M	M		280	45	01	310	81	24	310	56	05	280	32	03	290	41	02	210	25	17	8
9	M	M		M	M		240	29	11	290	92	07	300	50	23	290	46	20	270	28	24	320	38	23	9
10	M	M		M	M		340	32	23	280	88G	12	300	85G	16	300	46	05	260	38	22	330	29	01	10
11	M	M		M	M		300	43	17	270	52	04	300	66G	03	290	44	04	260	46	02	090	17	14*	11
12	M	M		M	M		290	45	12	260	50	04*	310	42	07	290	45	09	280	40	06	340	17	05*	12
13	M	M		M	M		280	30	05	270	40	06	300	55	18	260	40G	07	100	18	16	340	21	10	13
14	M	M		M	M		290	27	02	280	50	24	320	45	04	290	56	21	260	25	06	300	28	17	14
15	M	M		M	M		330	45	11	280	57	01	290	41	14	290	69G	03	310	26	23	M	M		15
16	M	M		M	M		300	45	03	290	52	24	280	50	11	300	46	07	310	25	01	M	M		16
17	M	M		300	37	10	250	30	01	290	50	24	220	27	12	320	40	19	140	22	13	M	M		17
18	M	M		280	31	08	280	35	24	300	49	02	310	50	23	300	51	23	110	35	12	M	M		18
19	M	M		310	63	10	280	32	03	300	53	23	310	46	02*	300	55	04	090	40G	11	290	41	09*	19
20	M	M		270	51	13	300	30	24	280	69	13	M	M		300	50	13	300	48	24	290	35	04	20
21	M	M		260	60G	16	330	36	02	290	46	01	M	M		280	37	04	300	47	01*	130	25	14	21
22	M	M		280	52G	10	290	65G	16	280	56	06	M	M		290	37	16	360	10	16	130	31	13	22
23	M	M		290	44	13	320	56	03	300	50	19	330	26	17*	270	34	21	110	22	11	350	37	14	23
24	M	M		270	45	23	290	90G	23	290	65G	23	330	40	24	290	50	12	110	28	23	310	50	06	24
25	M	M		260	45	13	300	61	02	280	60	02	310	55	01	290	40	10	130	26	01	290	26	04	25
26	M	M		260	30	03	300	32	01	290	59	05	310	72	05	260	43G	04	290	30	24	110	28	23	26
27	M	M		290	38	08	280	54	07	300	47	11	310	50	06	270	42	09	290	41	11	120	21	14	27
28	M	M		270	36	13	290	50	24	300	60	20	300	24	13	290	40	16	290	25	02	150	26	15	28
29	M	M		260	45	13	260	56	09	300	70	23				290	40	01	310	42	24	M	M		29
30	M	M		270	71G	20	300	75G	04	300	72	16				240	33	24	310	41	01	M	M		30
31	M	M					300	72	05	310	54	01				310	49	17				M	M		31
MONTHLY MAX				270	71G	20	290	90G	23	290	92	07	300	85G	16	290	69G	03	300	48	24	310	50	06	MAX
AVE					46			46			55			48			44			33			28		AVE

YEARLY MAX -- 92 MPH ON JAN 9 AT 0700 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOLD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1971-72

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		280	51	18	110	19	13	280	79G	21	260	26	01	300	54	06	310	44	16	290	51	18	1
2	M	M		280	49	19	270	20	24	290	100G	02*	290	43	24	270	51	12	300	51	01	330	36	03	2
3	M	M		290	55	13	260	28	08	090	65	10*	290	65	16	280	71	13	310	45	08	310	40	08	3
4	M	M		300	51	03	290	20	24	300	75	23	290	46	03	270	61	06	300	40	01	300	34	09	4
5	M	M		280	50	04	300	52	18	290	76G	01	290	37	13	270	65	22	280	51G	22	090	15	18	5
6	350	10	24*	290	49	04	280	42	09	290	75	04	320	24	03	260	77	15*	300	51	24	090	14	03*	6
7	090	26	17*	290	40	05	110	35	12	260	49	22	310	37	16	250	62G	02	300	50	01	M	M		7
8	340	20	21	300	35	05	280	23	13	290	60	24	320	30	08	290	51	07	270	32	22	M	M		8
9	340	22	04	290	39	20	290	40	13	290	91G	12	280	32	10	280	36	05	270	29	04	M	M		9
10	340	24	13	290	25	12	280	42	04	280	78G	16	M	M		280	33	10	270	40	13	250	24	15	10
11	300	36	22*	280	21	05	280	30	24	280	95G	17	310	45	24*	260	35	04	250	41	03	340	24	23	11
12	310	52	04	280	21	11	280	35	03	300	74	23	300	60	05	280	40	13	290	42	08	320	45	24	12
13	300	47	24	300	45	09	090	26	21	290	82G	06	290	55	14	270	32	11	250	26	01	330	51	03	13
14	M	M		270	25	02	290	46	21	290	70	14	300	47	13	300	45	19	100	21	10	340	24	16	14
15	130	33	21	130	30	09	280	35	02	290	63	01	290	55	10	290	41	09	320	36	15	310	20	01	15
16	120	50	22	110	27	02	290	55	06	300	46	03	290	66	23	280	49	16	330	27	01	M	M		16
17	120	57	13	330	14	02	290	39	21	290	70	23	290	64	16	280	41	01	250	41	02	130	22	13*	17
18	310	31	20	350	33	23	290	42	03	300	79G	06*	300	59	01	280	34	06	220	30	14	150	29	24	18
19	320	23	22	330	38	12	300	66	24	290	54	02	290	41	08	240	30	02	120	39	08	160	35	01	19
20	320	21	01	330	36	05	290	85	02	300	42	18	280	36	06	310	31	06	320	35	21	200	42	23	20
21	290	20	05*	330	19	23	260	50	02	290	64	10	300	40	03	280	44	03	300	44	12	130	30	14	21
22	280	15	20	340	21	23	280	51	02	M	M		270	41	11	260	35	03	280	59	03	320	24	01	22
23	310	26	04	300	48	24	280	60	14	250	50G	12*	270	35	15	300	44	19	300	32	06	290	24	12*	23
24	260	28	04	300	48	07	250	50	14	270	60	07	280	40	15	300	40	11	290	25	07	240	18	16	24
25	120	36	23	290	40	20	260	52G	05*	240	44	14	310	38	17	250	40	21	340	28	24	290	21	22	25
26	310	51	17	290	55	09	230	35	12*	230	31	01	270	70	21	260	40	08	350	45	11	100	26	17*	26
27	270	39	05	290	41	06	280	40	08	270	41	16	280	60	11	090	28	24	320	30	01	M	M		27
28	110	41	19*	300	37	21	260	30	11	280	50	22	270	50	03	090	39	04	310	35	14	M	M		28
29	120	48	13*	300	34	11	280	47	13	290	41	02	230	4xG	08	310	22	01	300	29	04	M	M		29
30	300	63	08	300	25	01	290	62	20	310	29	01				320	43	20	310	40	23	M	M		30
31	250	28	01				290	55	23	290	26	19				320	50	08				M	M		31
MONTHLY MAX	300	63	08	290	55	13	290	85	02	290	100G	02	270	70	21	260	77	15	280	59	03	290	51	18	MAX
AVE		34			37			42			62			46			44			38			30		AVE

YEARLY MAX -- 100G MPH ON JAN 2 AT 0200 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1972-73

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	300	36	24	320	45	21	310	69	01	340	26	15	310	34	16	330	31	03	090	39	24	M	M		1
2	320	35	01	350	35	01	290	65G	14	330	31	19	330	30	06	310	25	04	090	36	01	310	38	16*	2
3	340	35	08	350	20	11	310	44G	01	250	24	20	310	35	23	300	20	19	360	28	14	M	M		3
4	160	31	16	290	22	16	270	31	18	270	21	23	300	42	04	130	26	16	350	30	15	M	M		4
5	300	20	04	290	28	12	310	33	17	310	40	11	310	36	07	310	40	13	330	39	18	M	M		5
6	340	14	08	330	26	04	270	36	09	280	37	01	280	31	05	310	36	20	290	49	11	M	M		6
7	090	20	16	250	36	13	250	35	09	280	32	22	290	35	01	300	35	07	090	55	10	M	M		7
8	290	22	24	280	35	03	250	32G	14	290	35	24	340	11	01	120	29	11	310	51	17	M	M		8
9	300	45	07	330	33	24	310	26	14	290	31	01	310	30	24	150	18	11	330	50	02	M	M		9
10	250	47	05	300	36	07	270	34	13	330	42	14	300	36	07	340	24	23	310	44	02	M	M		10
11	260	30	02*	120	17	24	260	26	01	310	50	20	270	26	01	320	34	05	320	16	01	M	M		11
12	290	20	03	090	35	13	310	42	11	310	60G	02	330	45	19	160	37	24	330	24	06	M	M		12
13	330	41	12	350	26	02	280	34	08	300	75G	07	330	21	05	160	40	01	240	24	13	M	M		13
14	240	30	24	300	35	03	320	51	20	300	39	01	300	26	04	320	31	02	230	31	15	M	M		14
15	310	66	10*	330	41	18	310	42	19	310	34	24	340	19	08	320	25	18	320	36	19	M	M		15
16	300	55	13*	350	26	01	310	41	02	300	40	24	320	21	04	310	22	17	300	49	24	M	M		16
17	300	50	03	140	21	12	320	37	18	310	45	24	360	18	05	310	20	01	310	55	01	M	M		17
18	120	26	22	330	25	18	300	40	03	310	56G	05	330	29	08	290	14	03	140	31	16	M	M		18
19	140	24	13	320	24	06	310	65	12	260	35	06	310	40	12	330	10	07	320	65	19	M	M		19
20	090	32	15*	090	40	13	320	50	06	350	27	24	310	37	08	140	36	24	310	56	04	M	M		20
21	M	M		330	31	16	300	51	11	340	31	02	090	16	24	190	41	09	300	24	08	M	M		21
22	M	M		350	22	01	310	50G	22	340	30	20*	090	42	10	300	44	07	310	42	09	M	M		22
23	M	M		330	17	24	310	50	01	350	29	02	350	25	16	090	30	20	280	24	03	M	M		23
24	M	M		330	59	19	290	42	11	360	20	01	310	20	03	350	22	18	250	12	11	M	M		24
25	M	M		330	51	12	320	45	08	280	19	06*	310	44	08	310	24	22	320	38	15	M	M		25
26	M	M		310	88G	07	310	51	18	090	29	09	310	36	04	310	27	05	350	31	22	M	M		26
27	300	21	01	320	70	02	300	41	05	340	24	21	300	26	02	090	31	10	350	29	01	M	M		27
28	300	35	12	310	55	05	120	33	24	310	49	24	300	28	02	110	24	13	290	49	06	M	M		28
29	100	37	24	310	70G	18	340	37	24	280	50	24				120	26	10	270	42	06	M	M		29
30	120	40	11*	310	69	24	320	50	04	280	57G	02				330	30	24	090	27	15	M	M		30
31	090	32	22				330	33	01	280	23	01				310	39	17				M	M		31
MONTHLY MAX	310	66	10	310	88G	07	310	69	01	300	75G	07	330	45	19	300	44	07	320	65	19	310	38	16	MAX
AVE		34			38			42			37			30			29			38			38		AVE

YEARLY MAX -- 88G MPH ON NOV 26 AT 0700 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1973-74

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	320	28	05	280	55G	06	250	45	23	110	29	13	310	47	01	260	64	03	320	54	01	310	47	09	1
2	300	30	07	230	34	13	230	41	01	300	17	06	320	55	04	250	51	11	310	41	19	300	47	04	2
3	M	M		250	38	13	340	33	22	270	41	22	300	60	18	300	36	03	350	36	12	280	36	04	3
4	M	M		260	48	24	320	45	09	280	37	01	290	73	06	320	57	22	300	43	23	110	16	21	4
5	300	45	24	260	50	01	310	45	03	270	45	17	270	29	02	310	48	19	290	55	03	270	20	23	5
6	300	45	01	320	61	23	320	36	11	310	56	11	310	32	23	310	51	04	300	60	24	300	37	23	6
7	270	25	06	320	58	01	310	61	17	290	52	08	330	38	23	250	47	22	310	51	01	310	45	23	7
8	230	25	12	310	54	12	310	52	10	280	42	19	320	48	18	240	36	03	310	41	05	310	43	06°	8
9	130	26	01°	310	38	03	310	46	08	280	37	01	300	57	16	090	45	16	140	39	18	M	M		9
10	100	20	16	290	41	08	310	63	14	290	55	19	300	55	01	320	50	24	340	31	20	M	M		10
11	330	30	06	300	41	07	280	56G	21	290	51	08	310	45	12	310	62	03	320	62	19	M	M		11
12	310	56	24	280	55G	20	300	80	06	300	50	18	280	45	05	290	36	23	310	55	02	M	M		12
13	310	58	01	280	46G	01	290	55	21	310	54	21	300	40	02	280	45	18	340	36	15	250	50G	18°	13
14	340	26	01	310	71	22	310	54	19	310	74	19	340	23	23	290	45	10	320	37	23	290	41	01	14
15	310	22	01	300	40	07	310	52	10	310	57	01	M	M		300	53	08	330	44	14	250	53	04	15
16	310	30	13	290	50	08	310	56	11	310	40	22	M	M		310	58	04	300	33	04	260	35	06°	16
17	290	22	01	310	42	13	300	55	07	310	40	02	M	M		300	60	08	300	30	05	210	23	10°	17
18	320	26	16	250	35	12	310	27	02	310	52	22	330	45	14	290	51	01	120	21	21	120	27	15	18
19	090	21	17	090	36	09	340	25	20	310	50	05	300	38	02	270	37	15	140	32	11	130	55	18	19
20	300	36	24	310	53	23	310	57	21	310	39	04	350	26	01	280	40	03	310	51	21	260	35	19	20
21	310	40	03	310	50	01	320	48	01	310	37	07	320	45	15	300	42	24	300	44	20	280	42	02°	21
22	300	28	05	270	40	04	280	53	01	330	50	13	320	45	22	290	56	05	320	43	01	290	29	09°	22
23	240	44	10	290	36	24	360	21	10	340	34	08	310	54	03	310	51	11	180	26	21	M	M		23
24	300	65	07	310	46	02	340	40	20	330	32	07	320	38	18	300	54	09	280	32	07	M	M		24
25	280	36	05	290	42	20	310	69	10	290	44	21	330	33	08	310	56	05	280	27	04	M	M		25
26	310	31	24	300	31	02	300	45	22	310	50	03	280	43	02	290	36	01	260	35	09	M	M		26
27	310	45	14	310	73	21	310	67	17	330	45	23	270	60	16	270	44	07	270	45	06	M	M		27
28	320	35	01	310	61	01	320	70	19	320	59	21	290	50	01	310	70	24	240	15	04°	M	M		28
29	260	31	06	280	50	23	310	74	07	300	74	21				310	70	01	340	21	18°	M	M		29
30	290	50	24	290	46	04	310	55	05	310	76	23				280	60	01	310	25	21	M	M		30
31	290	52	04				310	39	06	310	66	02				320	51	24				M	M		31
MONTHLY MAX	300	65	07	310	73	21	300	80	06	310	76	23	290	73	06	310	70	24	320	62	19	130	55	18	MAX
AVE		35			47			50			48			45			50			34			38		AVE

YEARLY MAX -- 80 MPH ON DEC 12 AT 0600 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1974-75

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	290	31	12	300	25	03	310	36	06	100	27	09	280	45	10	310	47	07	320	40	24	310	33	09	1
2	310	26	05	110	19	14°	320	28	06	340	35	10	330	26	21	290	45	10	310	53	14	310	31	14	2
3	280	45G	24	090	16	02°	320	29	22	320	52	09	330	23	01	320	39	19	300	43	06	310	43	09	3
4	290	46	07	M	M		340	29	04	330	51	23	320	18	24	300	41	06	260	42	08	280	30	02	4
5	260	50	08	120	17	16	350	24	18	340	54	04	330	43	16	280	50	02	280	36	06	330	31	23	5
6	290	30	11	340	31	20	350	35	16	290	61G	03	320	51	24	310	51	13	170	46	23	310	43	10	6
7	300	27	04	330	25	09	330	30	01	290	56	05	310	55	01	310	35	04	310	56	22	310	43	08	7
8	320	25	04	110	32	23	330	22	24	310	41	02	290	47G	15	290	39	03	310	47	02	310	24	01	8
9	290	21	10	330	31	24	350	25	04	350	34	16	300	55	22°	330	30	15	310	33	03	090	15	17	9
10	270	31	06	320	49	23	100	20	01	330	42	11	330	45	17	320	27	10	100	36	24	290	25	09	10
11	110	30	24	300	53	24	310	61G	24	320	58G	04	330	64	03	350	19	14	110	36	14	320	25	10	11
12	090	26	02	300	65	07	310	74	01	310	57	22°	310	54	06	320	24	22	100	19	14	340	41	24	12
13	120	13	23	290	81G	02	300	42	02	310	57	24	290	64G	06	330	26	10	310	35	22	340	35	01	13
14	330	23	17	300	61	09	330	51	06	310	67G	18	100	38	23	090	30	24	310	40	02	350	24	01°	14
15	320	31	05	300	49	02	320	46	17	320	40	11	120	25	01	090	25	01	280	41	08	300	16	04	15
16	330	27	02	320	39	02	310	57G	18	320	49	07	110	24	22	300	29	01	250	31	03	090	16	13	16
17	350	16	14	290	33	24	300	43	09	310	57	23	100	35	04	310	45	23	260	28	01	350	20	02	17
18	110	11	02	290	52	20	320	47	15	310	67G	17	320	46	05	320	52	12	310	63	22	310	35	21	18
19	330	25	14	310	46	02	320	56	11	310	50	16	320	50	14	300	56	07	320	55	06	310	37	06	19
20	300	18	11	300	56	05°	320	60G	18	310	65	07	300	51	17	290	46	06	310	30	10	140	55	24	20
21	290	22	06	310	37	02	280	51G	22	090	42	06	100	32	20	260	43	23	160	18	13	160	57	02	21
22	100	26	01	270	22	01	330	55	05	330	39	07	320	32	17	250	47	05	250	30	08	140	30	09	22
23	310	25	24	310	39	18	120	52	17°	320	50	13	350	31	09	310	66	21	290	25	01	320	35	22	23
24	330	23	01	310	37	15	350	35	19	310	80	17	320	65	17	330	72	05	240	32	24	310	42	05	24
25	290	16	24	310	55	22	320	35	04	320	88	05	310	40	13	300	36	03	160	40G	21	320	35	06	25
26	310	19	04	300	55	19	300	23	01	290	54	12	310	42	21	100	38	21	170	46G	09	290	29	01	26
27	110	21	14	310	40	04	330	35	06	250	26	01	310	75	04	120	29	01	320	71G	23	280	33	03°	27
28	100	23	22	110	36	14	280	23	06	310	50	17	310	57	13	320	37	14	330	70G	01	090	31	21°	28
29	090	32	17	340	28	16	280	26	17	280	48	07				320	41	24	310	35	23	M	M		29
30	130	25	03	340	29	14	330	25	05	250	32	13				310	49	21	310	29	01	320	30	21°	30
31	310	33	22				340	29	21	280	30	07				310	47	01				320	31	15	31
MONTHLY MAX	260	50	08	290	81G	02	310	74	01	320	88	05	310	75	04	330	72	05	320	71G	23	160	57	02	MAX
AVE		26			40			39			50			44			41			40			33		AVE

YEARLY MAX -- 88 MPH ON JAN 25 AT 0500 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1975-76

MAXIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		340	20	24	310	60	05	320	22	11	310	56	14	250	37	13	250	33	23	310	35	24*	1
2	M	M		340	27	03	300	55	06	300	47	23	310	66	15	240	32	13*	290	46	08	310	34	01	2
3	M	M		340	35	15	300	30	01	300	46	07	300	70	01	270	29	05	310	31	07	320	20	02	3
4	M	M		340	13	01	300	30	02	300	53	15	240	38	11	310	34	14*	240	15	04	320	35	24	4
5	M	M		360	16	15	310	46	06	310	52	03	280	30	16	300	37	07	100	28	19*	320	45	02	5
6	M	M		310	42	22	310	50	13	300	35	02	310	29	13	340	23	05	M	M		M	M		6
7	M	M		280	38	09	310	49	21	310	52	20	300	61	14	090	22	24	330	36	15	M	M		7
8	M	M		250	25	02	310	53	17	300	44	04	300	56	05	310	26	17	220	26	23	340	23	24	8
9	M	M		300	37	23	300	43	24	290	40	01	270	40G	05	310	46	15	280	39	23	330	25	02	9
10	M	M		250	43G	10	300	44	01	310	40	15	300	45	06	300	40	04	290	42	07	130	19	16	10
11	M	M		310	70G	16	300	35	06	290	45	14	300	40	18	310	35	14	110	20	19	320	42	20	11
12	M	M		310	51	01	260	35	13	310	56	24	300	44	12	350	30	04	140	35	12	320	48	19	12
13	M	M		330	33	04	270	24	01	300	52	09	300	40	01	310	50	09	190	25	14	330	46	05	13
14	M	M		310	35	07	340	28	20	320	65	24	290	46	16	300	45	01	140	25	15	340	25	06	14
15	M	M		340	30	21	300	82	10	310	68G	19	300	35	22	310	44	17	340	26	24	340	21	17	15
16	M	M		310	32	04	300	47	14	310	55	01	290	55	22	310	56	04	310	32	09	300	24	15	16
17	340	33	01	270	28	02	300	53	07	310	37	17	310	54	18	310	44	17	350	28	20	310	34	04	17
18	330	24	23	130	34	13	340	31	04	300	39	13	280	70G	09	260	51G	24	320	30	01	310	24	10	18
19	300	28	24	350	32	17	330	25	01	330	26	23	270	34	05	330	55	22	330	29	20	130	28	14	19
20	310	38	04	340	32	04	300	15	22	310	32	08	100	35	05	310	62	08	300	45	23	100	20	13	20
21	300	33	15	350	21	20	330	22	08	330	26	06	340	28	09	310	58	19	300	54	09	110	19	14*	21
22	280	28	03	310	40	23	330	21	08	300	45	16	300	40	23	290	58	01	270	34	24	M	M		22
23	100	28	03	300	51	06	340	19	20	300	49	09	270	42	23	280	53	02	320	40	19	M	M		23
24	310	27	21	310	51	10	350	29	15	320	43	20	280	43	01	270	52	21	310	41	16	300	30	02	24
25	300	48	05	300	52	02	340	25	16	300	40	06	300	45	10	270	42	04	140	35	22	340	32	21	25
26	280	47	14	310	56	07	310	45	24	320	50	20	310	41	11	330	38	02	140	35G	07	350	24	01	26
27	270	45	01	300	46	01	310	66	07	340	38	01	300	32	07	270	28	04	100	22	02	290	21	24	27
28	280	32	05	270	28	17	340	22	04	330	37	02*	290	45	20	250	24	09	130	20	01	300	31	09	28
29	310	39	06	320	49	24	320	30	14	320	41	11	280	45	05	360	15	21	290	21	13	VAR	14	21	29
30	280	26	07	300	77G	06*	240	26	15	310	55G	15				320	39	22	340	23	20	310	24	21*	30
31	100	24	12				100	30	02	340	32	06				330	35	01				310	24	02	31
MONTHLY MAX	300	48	05	300	77G	06	300	82	10	310	68G	19	300	70	01	310	62	08	300	54	09	320	48	19	MAX
AVE		33			38			38			44			45			40			32			28		AVE

YEARLY MAX -- 82 MPH ON DEC 15 AT 1000 HOURS

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1968-69

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		350	4	15	310	18	22	290	35	24	300	17	12	080	3	15	280	5	23	270	12	21	1
2	M	M		330	14	17	310	19	07	330	25	24	310	27	02	070	8	04	230	5	01	220	6	06*	2
3	M	M		340	14	11	310	37	14	320	16	13	270	17	24	230	3	11	060	5	14	230	2	09	3
4	M	M		320	14	24	320	31	23	340	20	22	110	3	10	110	6	22	340	7	13	250	2	07	4
5	M	M		310	10	19	290	20	16*	310	26	01	310	24	07	210	9	02	010	5	18	090	1	02	5
6	M	M		320	10	09	290	17	11	300	32	01	260	9	17	100	3	22	230	14	01	090	7	22*	6
7	M	M		320	10	21	290	16	09	270	19	05	230	10	01	090	11	24	350	11	03	M	M		7
8	M	M		320	17	01	320	23	19	280	20	17*	330	14	14	090	1	02	330	16	20	M	M		8
9	M	M		320	31	11	240	4	18	260	25	12	290	20	12	260	1	23	350	5	18	M	M		9
10	M	M		310	36	17	290	20	12	250	26	15	320	30	13	240	1	05	340	1	19	M	M		10
11	M	M		310	31	20	240	9	19*	240	19	10	270	4	20	100	1	09	090	1	07	090	5	17	11
12	M	M		300	30	19	320	51	01	230	10	19	240	5	19	310	14	12	110	1	03	340	7	21	12
13	M	M		230	5	17	310	16	09	270	21	01	360	1	15	090	1	17	300	1	10	M	M		13
14	M	M		120	1	11	290	16	15	110	10	19	290	8	07	090	1	04	310	6	14	M	M		14
15	M	M		300	12	01	280	20	08	310	19	02	340	6	18	340	10	01	090	1	23	M	M		15
16	020	16	03*	280	35	06	250	11	19	210	6	19	140	1	11	340	14	09	110	2	16	M	M		16
17	320	18	03	300	39	24	290	8	12	290	19	02	320	16	03	340	14	10	360	2	05	M	M		17
18	290	22	19*	320	29	17	350	17	01	220	6	18	210	4	12	210	11	21	280	3	10	M	M		18
19	280	12	18	350	14	15	200	3	09	320	20	23	330	6	19	280	27	03	010	1	11	M	M		19
20	220	6	07	330	25	18	120	6	03	310	20	01	330	16	07	270	6	10	300	16	23	260	11	19*	20
21	310	25	02	080	7	05	340	3	14	270	16	18	250	6	19	100	1	19	270	1	23	340	2	19	21
22	330	35	09	330	20	02	340	40	01	280	10	23	240	3	23	340	5	12	130	1	01	290	6	24	22
23	330	33	23	340	12	04	310	24	14	240	9	05	300	5	17	020	9	23	190	6	03	110	1	02	23
24	330	11	24	320	12	09	310	22	20	260	21	13	260	15	01	340	1	03	180	10	05	290	1	20	24
25	320	11	13	240	11	02	260	20	13	250	13	11	230	20	19	310	30	01	310	21	01	290	4	18	25
26	310	17	01	090	1	14	310	5	21	240	16	24	310	12	18	320	21	22	300	20G	09	080	2	21	26
27	310	28	21	090	6	17	360	9	02	020	6	07	130	6	21	320	15	07	260	8	24	250	6	16*	27
28	310	11	20	090	1	04	310	25	01	230	9	02	240	4	19	290	27	09	270	9	20	280	5	09	28
29	260	5	08*	010	15	18	280	20	16	120	7	14*				310	24	20	260	10	19	250	1	04	29
30	360	9	15	070	3	19	280	34	04	300	20	02				300	19	20	260	13	20	280	10	01	30
31	330	10	09				320	34	21	290	30	19				280	15	17				320	14	07	31
MONTHLY MAX	330	35	09	300	39	24	320	51	01	290	35	24	320	30	13	310	30	01	310	21	01	320	14	07	MAX
AVE		17			16			19			18			11			10			07			05		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1969-70

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	HR	NOV DIR	NOV SPD	HR	DEC DIR	DEC SPD	HR	JAN DIR	JAN SPD	HR	FEB DIR	FEB SPD	HR	MAR DIR	MAR SPD	HR	APR DIR	APR SPD	HR	MAY DIR	MAY SPD	HR	DAY
1	M	M		M	M		010	1	17	040	4	05	340	20	19	240	11	10	360	9	01	100	4	01	1
2	M	M		M	M		020	3	02°	360	22	02	330	17	03	260	19	01	320	21	24	350	13	13°	2
3	M	M		M	M		130	4	06	310	27	19	310	32	19	320	10	03	100	1	07	M	M		3
4	M	M		M	M		250	10	01	080	3	22	310	30	06	270	11	19	320	21	01		0	24	4
5	M	M		350	17	20°	090	1	14	240	5	01	310	29	17	020	1	23	330	28	22		0	01	5
6	M	M		340	20	11°	010	24	02	310	27	14	320	31	22	330	5	01	330	2	14	200	3	01	6
7	M	M		170	10	14°	340	21	10°	260	42	16	310	14	19	330	21	23	270	17	01	290	1	07	7
8	M	M		M	M		M	M		270	34	10°	340	13	20	290	15	10	290	25	03	310	26	07	8
9	M	M		350	4	12	320	16	17	M	M		340	18	23°	250	6	20	030	1	14	310	25	12	9
10	M	M		310	15	15	340	15	04	330	33	10	360	15	03	120	4	09	300	21	21	240	15	12	10
11	M	M		300	22	02	330	31	16	330	29	18	340	14	02	030	3	07	300	14	09	100	5	18	11
12	M	M		300	30	01	330	37	12	020	18	24	300	14	23	360	13	02	320	28	22	270	3	24	12
13	M	M		300	44	02	330	25	16	020	15	01	300	22	01	320	30	21	240	10	13	M	M		13
14	M	M		270	18	17	340	25	15	350	24	02	350	14	11	300	16	23	360	16	20	M	M		14
15	M	M		230	12	12	320	20	13	290	11	08	350	20	10	340	1	11	270	10	23	M	M		15
16	M	M		190	14	20	270	7	10	360	19	02	280	29	23	090	1	02	200	7	07	M	M		16
17	M	M		M	M		300	14	23	320	23	16	290	25	09	260	14	07	110	9	18	M	M		17
18	M	M		010	28	02	330	12	13	310	28	04	340	16	20	350	5	23	180	10	03	M	M		18
19	M	M		010	27	04°	300	18	04	300	40	01	350	13	02	330	11	06	320	18	19	M	M		19
20	M	M		340	18	13	300	34	04	320	27	02	200	5	24	350	5	11	310	30	01	M	M		20
21	M	M		320	15	03	270	27	18	290	37	08	050	4	19°	350	23	02	200	9	09°	M	M		21
22	M	M		360	10	15	300	37	20	280	26	03	120	2	03	320	25	01	290	10	19	M	M		22
23	M	M		050	6	04	290	24	13	250	28	24	230	4	01	300	32	03	290	15	10	M	M		23
24	M	M		340	8	22	250	12	08	260	28	04		0	23	120	5	21	290	20	11	M	M		24
25	M	M		340	1	06	290	14	22	260	15	17	320	12	01	100	11	03	290	14	19	M	M		25
26	M	M		340	6	22	360	11	23	290	14	08	350	29	13	090	3	17	240	15	19	M	M		26
27	M	M		040	1	13	290	1	02	240	21	18	310	10	11	090	1	13	200	8	11	M	M		27
28	M	M		360	1	13	280	5	23	310	18	04	220	8	19	350	10	22	010	7	03	M	M		28
29	M	M		020	6	08	340	10	01	330	24	17				030	1	11	350	9	19	M	M		29
30	M	M		100	11	01	010	12	08	270	7	11				120	11	24	360	3	23	M	M		30
31	M	M					010	15	24	350	12	13				270	3	23				M	M		31
MONTHLY MAX				300	44	02	330	37	12	260	42	16	310	32	19	300	32	03	310	30	01	310	26	07	MAX
AVE					14			16			22			16			11			14			09		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1970-71

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	HR	NOV DIR	NOV SPD	HR	DEC DIR	DEC SPD	HR	JAN DIR	JAN SPD	HR	FEB DIR	FEB SPD	HR	MAR DIR	MAR SPD	HR	APR DIR	APR SPD	HR	MAY DIR	MAY SPD	HR	DAY
1	M	M		M	M		300	14	15°	300	5	21	330	5	17	090	3	11	290	27	24	090	3	22	1
2	M	M		M	M		250	22	07	210	10	01	300	10	22	090	7	04°	290	22	18	090	5	23	2
3	M	M		M	M		320	17	13	110	24	24	090	4	11	330	27	01	VAR	5	23	110	1	22	3
4	M	M		M	M		280	25	16	330	9	06	310	22	13	130	7	22	090	6	01	250	5	09	4
5	M	M		M	M		320	20	08	310	19	23	330	24	18	330	10	12°	320	12	24	300	4	23	5
6	M	M		M	M		320	21	07	290	19	01	320	20	01	290	29	01	VAR	2	19	030	2	01	6
7	M	M		M	M		280	17	11	330	20	19	310	24	03	290	34	21	250	15	12		0	08	7
8	M	M		M	M		240	7	21	320	32	02	320	35	20	310	11	17	VAR	1	21	330	5	14	8
9	M	M		M	M		260	7	19	280	23	20	320	24	14	320	26	08	200	M	01	310	10	01	9
10	M	M		M	M		340	13	01	310	31	05	300	45	05	300	26	14	260	15	19	080	4	23	10
11	M	M		M	M		350	20	08	270	37	21	310	40	23	260	9	24	230	15	19	080	3	02°	11
12	M	M		M	M		300	26	04	240	20	20°	340	20	21	250	9	01	300	8	20	060	1	23°	12
13	M	M		M	M		320	15	15	260	17	12	330	23	01	250	10	15	340	6	07	270	5	15	13
14	M	M		M	M		270	14	16	280	20	04	320	19	13	340	17	01	280	8	21	300	12	19	14
15	M	M		M	M		330	14	01	310	36	17	310	20	01	290	20	15	090	1	07	M	M		15
16	M	M		M	M		290	30	06	310	26	07	270	10	20	240	15	21	VAR	2	08	M	M		16
17	M	M		310	23	24	230	18	21	270	26	04	060	3	24	290	19	15	220	7	06	M	M		17
18	M	M		310	13	21	240	6	03	340	21	16	010	3	09	310	25	01	VAR	3	05	M	M		18
19	M	M		300	26	01	260	19	24	010	20	09	290	10	14°	290	30	24	090	6	22	270	18	21°	19
20	M	M		290	28	01	200	9	14	280	36	18	M	M		300	25	21	340	10	01	160	6	19	20
21	M	M		270	31	24	280	23	18	290	20	09	M	M		300	24	24		0	20°	180	6	06	21
22	M	M		320	21	23	270	21	04	280	20	17	M	M		300	24	01		0	06	160	10	09	22
23	M	M		290	25	21	340	28	16	310	26	02	340	14	09°	260	21	13	VAR	4	01	040	6	07	23
24	M	M		290	16	10	280	35	01	320	31	15	350	24	12	250	21	03	230	9	14	290	20	23	24
25	M	M		250	21	22	320	30	11	270	14	06	340	22	17	300	24	01	110	11	22	120	5	23	25
26	M	M		350	12	11	260	19	24	340	25	10	350	29	17	260	20	16		0	04	260	9	05	26
27	M	M		270	10	21	270	22	19	300	19	21	200	7	22	260	10	20	290	18	21	150	10	02	27
28	M	M		270	14	01	300	20	08	350	16	04	330	3	22	290	22	20	240	2	19	090	9	20	28
29	M	M		300	14	07	280	27	16	310	41	01				320	20	12	320	17	01	M	M		29
30	M	M		200	25	06	320	36	01	320	45	14				270	20	16	290	11	19	M	M		30
31	M	M					290	25	21	290	9	22				310	20	12				M	M		31
MONTHLY MAX				270	31	24	320	36	01	320	45	14	300	45	05	290	34	21	290	27	24	290	20	23	MAX
AVE					20			20			23			18			19			08			07		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
° = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1971-72

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		300	13	01	210	4	09	300	40	11	300	5	20	290	26	15	330	29	10	320	25	06	1
2	M	M		310	29	10	110	5	02	350	11	21*	350	6	01	270	25	20	290	25	13	330	15	22	2
3	M	M		290	44	06	300	10	15	110	10	21*	290	40	07	280	34	20	310	25	20	270	10	21	3
4	M	M		270	29	19	300	5	20	310	24	01	290	29	22	290	32	18	300	15	20	VAR	9	22	4
5	M	M		260	20	09	300	16	02	280	47	03	330	25	24	270	42	01	300	25	14	090	5	15	5
6	240	2	01*	300	15	16	300	8	18	310	29	24	340	16	13	260	39	22*	280	25	15	120	6	15*	6
7	350	3	09*	310	6	15	270	3	02	330	19	06	320	19	20	290	28	20	310	2	20	M	M		7
8	320	10	04	320	12	23	250	6	04	290	30	18	320	16	13	270	18	21	210	5	06	M	M		8
9	330	6	12	260	10	10	300	13	20	260	49	24	200	7	18	310	16	12	280	12	20	M	M		9
10	340	7	09	260	11	19	260	10	23	280	42	24	M	M		250	18	21	280	23	08	160	7	05	10
11	320	6	02*	290	11	24	230	3	11	270	43	05	320	14	08*	270	14	18	240	16	24	150	5	05	11
12	330	5	21	220	6	18	210	15	19	280	50	12	310	26	18	300	10	20	230	16	01	350	21	01	12
13	330	14	09	300	10	06	240	1	08	290	35	23	310	30	11	290	16	21	210	9	18	320	10	24	13
14	M	M		150	10	16	130	9	01	290	35	01	300	15	22	310	19	10	340	5	20	340	12	04	14
15	170	11	15	190	16	01	260	12	21	320	40	18	310	15	01	320	20	03	350	14	01	270	1	23	15
16	120	11	04	310	5	22	280	28	01	300	25	16	300	35	18	290	34	23	330	10	08	M	M		16
17	270	8	24		0	23	300	13	12	330	25	12	310	50	04	290	20	23	270	9	19	260	9	23*	17
18	290	15	01	110	4	01	290	20	11	280	25	17*	310	25	19	260	12	21	140	10	03	230	6	07	18
19	310	14	14	330	21	20	310	39	01	290	24	24	290	19	21	210	10	07	290	8	22	130	15	06	19
20	290	3	12	340	10	17	300	46	11	310	21	04	300	19	19	320	20	02	040	1	03	100	10	08	20
21	240	4	17*	150	10	03	270	20	10	360	30	02	020	3	16	280	17	19	290	19	21	290	7	12	21
22	090	4	10	340	10	05	270	32	12	M	M		270	15	21	020	6	12	310	10	23	090	4	07	22
23	260	7	20	320	19	03	290	25	23	300	27	23*	270	21	19	180	4	06	300	10	23	250	5	07*	23
24	170	10	16	280	20	22	230	18	03	270	24	17	270	20	22	270	14	20	270	7	01	120	8	21	24
25	210	7	11	290	16	01	240	34	17*	250	24	10	330	16	10	240	19	18	230	10	05	220	3	05	25
26	270	10	04	310	21	01	300	10	16*	230	18	09	270	26	02	320	12	22	330	24	01	180	5	06*	26
27	180	15	19	260	20	11	250	16	20	220	20	07	300	33	09	090	1	17	320	20	09	M	M		27
28	190	14	02*	330	20	06	190	15	22	270	27	09	260	29	13	330	9	13	310	21	01	M	M		28
29	300	3	21*	320	16	07	210	10	04	290	20	22	230	20	17	310	6	09	230	12	20	M	M		29
30	340	20	01	020	2	18	290	29	01	330	17	24				310	24	01	310	14	03	M	M		30
31	280	6	19				320	27	13	320	15	02				310	29	24				M	M		31
MONTHLY MAX	340	20	01	290	44	06	300	46	11	280	50	12	310	50	04	270	42	01	330	29	10	320	25	06	MAX
AVE		09			15			16			28			21			19			14			09		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1972-73

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	020	7	06	030	9	03	310	38	11	150	5	04	360	7	01	310	10	17	090	5	15	M	M		1
2	150	10	19	340	13	16	320	30	21	010	8	01	340	20	12	360	3	17	070	5	24	320	20	06*	2
3	150	6	20	350	10	03	290	23	24	270	8	06	330	6	10	010	4	15	040	6	02	M	M		3
4	240	7	08	360	4	08	360	9	22	250	10	08	330	13	16	190	5	09	350	4	02	M	M		4
5	090	1	20	300	11	16	300	10	06	270	15	02	330	17	18	260	15	03	350	11	03	M	M		5
6	180	2	22	330	16	02	290	21	20	280	10	15	250	6	16	310	20	01	270	4	22	M	M		6
7	220	3	21	260	15	22	210	15	24	310	15	02	330	10	22	020	3	18	270	4	01	M	M		7
8	260	6	18	360	9	23	230	5	23	280	20	02	180	1	10	130	10	07	360	11	01	M	M		8
9	250	11	23	340	23	01	180	5	03	320	13	16	010	1	02	230	3	17	320	34	06	M	M		9
10	270	15	21	200	9	17	280	22	10	350	16	23	320	27	01	350	11	07	320	20	24	M	M		10
11	280	8	20*	270	5	20	090	3	15	350	18	01	200	2	18	120	5	21	270	1	21	M	M		11
12	300	5	19	010	6	20	350	16	01	300	30	15	240	10	01	190	9	15	310	5	01	M	M		12
13	240	14	01	300	5	19	330	13	14	330	30	24	360	10	13	090	8	12	240	11	19	M	M		13
14	190	8	05	250	7	16	330	18	01	330	10	08	330	15	02	330	5	23	260	9	20	M	M		14
15	290	26	02*	330	6	04	310	29	02	350	10	08	320	5	17	340	5	01	090	2	13	M	M		15
16	330	32	23*	330	10	08	290	13	08	340	24	12	310	1	10	330	15	09	360	16	04	M	M		16
17	300	10	24	120	5	17	320	21	03	320	20	10	140	1	09	270	6	21	280	8	20	M	M		17
18	270	3	16	280	4	02	350	16	20	290	20	17	300	7	19	070	4	17	360	4	19	M	M		18
19	VAR	4	08	090	1	17	350	17	01	020	9	21	340	20	21	320	4	03	340	28	01	M	M		19
20	260	12	02*	120	15	01	320	30	16	060	5	04	150	4	24	240	5	09	310	16	22	M	M		20
21	M	M		350	1	04	340	22	03	360	15	24	210	1	06	010	13	17	340	13	15	M	M		21
22	M	M		090	3	10	280	19	18	010	4	13*	090	14	19	320	11	18	360	11	21	M	M		22
23	M	M		270	2	19	340	19	20	350	13	16	220	11	03	020	4	23	360	5	18	M	M		23
24	M	M		350	17	04	340	11	03	210	2	10	350	10	01	360	5	08	270	1	19	M	M		24
25	M	M		320	37	05	350	25	22	330	4	12*	340	15	22	010	10	07	300	8	22	M	M		25
26	M	M		310	44	01	340	29	01	090	1	05	310	13	17	340	10	18	120	4	01	M	M		26
27	210	4	21	340	18	19	270	16	10	030	3	12	360	10	14	090	1	24	290	19	20	M	M		27
28	310	16	01	340	30	19	250	3	08	010	8	03	270	1	16	130	1	06	280	10	22	M	M		28
29	150	19	16	330	33	02	360	5	13	320	26	14				120	5	24	210	11	21	M	M		29
30	090	14	21*	320	55	04	340	35	20	300	4	23				270	2	02	090	4	20	M	M		30
31	090	2	13				120	3	18	330	1	04				340	26	07				M	M		31
MONTHLY MAX	330	32	23	320	55	04	310	38	11	300	30	15	320	27	01	340	26	07	320	36	06	320	20	06	MAX
AVE		10			14			17			12			09			08			10			20		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

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CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1973-74

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	SPD	HR	NOV DIR	SPD	HR	DEC DIR	SPD	HR	JAN DIR	SPD	HR	FEB DIR	SPD	HR	MAR DIR	SPD	HR	APR DIR	SPD	HR	MAY DIR	SPD	HR	DAY
1	280	7	20	250	13	23	290	14	14	240	2	20	300	28	14	250	20	20	250	19	16	280	23	20	1
2	250	15	12	270	15	02	360	11	11	200	2	03	340	25	14	250	26	04	210	6	10	290	12	22	2
3	M	M		220	20	20	090	5	10	280	13	11	330	30	12	270	12	11	340	23	24	270	8	24	3
4	M	M		340	18	05	350	27	07	260	20	24	280	30	23	320	23	01	340	15	06	280	6	01	4
5	290	12	02	300	31	12	330	24	22	200	15	08	090	5	24	330	25	07	280	28	23	VAR	1	10	5
6	240	13	18	290	31	05	350	23	20	290	35	06	360	1	02	260	31	23	280	13	15	310	12	14	6
7	250	12	08	300	35	09	340	23	06	300	29	12	100	2	09	230	15	13	320	30	18	320	25	09	7
8	200	8	09	300	36	07	330	23	06	330	19	10	320	26	14	280	13	19	290	23	24	290	25	14*	8
9	140	4	08*	260	15	20	320	27	01	270	13	16	320	29	05	110	9	03	230	15	08	M	M		9
10	090	2	03	290	19	19	320	28	04	320	23	01	340	25	21	110	9	04	350	14	03	M	M		10
11	350	14	01	300	21	22	290	35	12	290	31	16	340	24	01	340	17	23	340	24	02	M	M		11
12	320	25	01	290	20	02	310	30	17	320	25	22	280	28	21	310	5	08	350	9	19	M	M		12
13	350	18	21	230	22	13	300	18	05	320	24	15	330	13	24	320	19	04	350	14	10	250	25	12*	13
14	300	9	10	270	23	04	330	28	08	290	20	09	330	13	01	270	28	02	330	14	06	280	19	06	14
15	090	4	11	310	19	15	330	34	20	320	28	14	M	M		300	34	03	310	19	19	230	20	21	15
16	250	14	01	290	19	18	300	30	20	320	16	09	M	M		300	27	19	320	11	09	210	14	17*	16
17	360	3	10	310	20	24	310	17	24	020	2	19	M	M		310	42	11	210	5	23	300	13	20*	17
18	330	15	10	290	7	22	050	2	23	VAR	1	08	340	13	03	280	12	15	260	6	10	230	4	05	18
19	050	3	10	270	10	05	040	4	01	330	21	23	310	15	19	330	19	01	180	7	04	160	15	01	19
20	240	10	01	010	11	01	330	28	08	290	8	18	350	11	23	320	23	19	350	9	02	270	15	01	20
21	350	7	19	290	10	16	300	17	13	120	2	11	360	9	07	290	27	20	330	23	17	260	30	07*	21
22	300	10	18	170	8	20	190	5	17	340	20	01	250	24	11	270	19	10	270	6	20	250	7	24*	22
23	260	11	01	170	12	04	040	8	19	330	10	21	340	31	06	310	30	19	250	9	09	M	M		23
24	280	10	21	170	4	22	360	15	03	340	17	01	340	24	08	300	26	17	VAR	8	13	M	M		24
25	290	9	22	250	12	08	340	19	24	310	16	03	320	20	12	280	20	19	VAR	2	18	M	M		25
26	150	9	02	130	3	13	340	18	02	340	10	18	280	25	19	300	9	16	240	7	01	M	M		26
27	320	30	08	340	25	01	280	32	09	330	18	01	290	20	20	330	13	01	250	11	21	M	M		27
28	270	15	21	330	20	11	290	45	01	320	28	11	310	25	23	280	30	17	150	8	14*	M	M		28
29	250	7	10	280	25	15	310	43	24	340	40	04				280	36	21	110	4	14*	M	M		29
30	340	9	02	280	14	19	320	19	09	320	50	19				310	15	20	210	4	14	M	M		30
31	290	28	17				280	19	24	300	38	22				280	13	05				M	M		31
MONTHLY MAX	320	30	08	300	36	07	290	45	01	320	50	19	340	31	06	310	42	11	320	30	18	260	30	07	MAX
AVE		11			18			22			19			20			21			13			15		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
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* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT. WINTER 1974-75

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	SPD	HR	NOV DIR	SPD	HR	DEC DIR	SPD	HR	JAN DIR	SPD	HR	FEB DIR	SPD	HR	MAR DIR	SPD	HR	APR DIR	SPD	HR	MAY DIR	SPD	HR	DAY
1	280	16	01	160	1	18	300	11	22	240	3	18	330	18	17	310	19	21	160	10	06	230	5	19	1
2	280	11	22	160	5	09*	320	13	01	350	22	17	130	6	10	320	24	24	310	35	24	300	14	01	2
3	310	5	18	180	1	20*	340	18	17	350	23	01	210	1	21	320	20	01	290	21	18	270	13	20	3
4	210	10	18	M	M		320	4	19	350	25	19	330	1	04	310	27	11	240	11	21	220	6	24	4
5	300	9	24	050	1	07	290	3	04	320	29	22	300	5	08	350	13	19	210	10	17	180	7	01	5
6	260	8	02	240	2	01	350	18	21	270	18	19	350	25	02	260	20	03	170	15	09	310	28	21	6
7	320	18	08	010	5	20	030	1	10	290	30	11	280	30	24	320	20	10	090	4	13	320	19	19	7
8	020	6	18	240	1	02	090	5	01	300	16	21	300	24	03	280	5	19	310	30	22	230	7	21	8
9	030	6	19	100	5	07	090	4	20	330	6	04	290	22	01*	120	4	05	130	2	20	190	3	02	9
10	030	4	20	320	20	11	120	2	03	340	27	01	280	10	10	210	5	02	090	16	15	260	4	22	10
11	180	3	01	300	34	02	350	18	01	320	44	11	340	25	20	090	6	16	140	7	24	150	2	01	11
12		0	19	300	38	18	310	28	05	340	35	13*	330	31	16	320	8	12	050	2	20	250	15	06	12
13	330	2	20	310	50G	08	270	25	04	320	35	01	350	19	24	340	8	19	090	5	03	360	19	12	13
14	210	4	01	310	43	17	330	31	12	300	36	24	270	1	07	360	6	15	240	9	20	350	9	10*	14
15	340	21	12	300	22	10	330	30	12	290	19	19	100	5	22	090	2	13	220	5	21	210	5	24	15
16	360	6	23	330	20	12	340	35	08	340	28	23	300	8	18	260	13	10	260	15	21	010	4	20	16
17	110	1	07	330	13	21	330	26	05	340	20	10	150	4	13	340	10	04	010	6	14	160	5	16	17
18	110	1	18	300	30	03	310	26	24	330	30	24	350	21	22	320	30	08	300	5	07	090	7	12	18
19	270	1	21	330	27	13	310	25	01	330	34	02	340	25	01	300	12	18	360	5	24	270	14	19	19
20	030	1	21	290	30	24*	320	32	10	300	31	11	340	28	24	270	24	17	140	5	01	240	11	05	20
21	270	7	15	290	19	24	290	23	15	150	4	17	270	6	14	280	6	04	160	9	08	130	20	23	21
22	130	7	14	350	6	16	350	5	24	350	19	12	140	5	06	250	24	15	210	12	01	280	9	05	22
23	240	1	09	310	10	01	120	10	06*	320	23	05	340	20	22	330	40	01	270	10	07	340	17	02	23
24	080	3	20	340	22	11	260	15	02	310	41	01	350	23	03	310	30	24	210	8	19	290	10	22	24
25	150	1	03	270	17	09	360	5	12	290	56	24	320	23	20	280	10	07	230	19G	19	190	7	21	25
26	300	7	19	340	26	06	030	1	08	260	26	22	310	27	09	090	8	12	170	16	06	260	3	22	26
27	090	5	09	340	12	24	340	17	15	230	14	06	330	30	19	300	6	08	020	15	11	120	1	21*	27
28	100	2	04	130	4	04	200	1	15	220	12	10	310	29	03	340	19	01	310	29	21	090	10	24*	28
29	130	10	24	350	16	01	340	9	14	280	20	18				340	26	03	340	10	12	M	M		29
30	010	7	12	350	15	01	090	8	23	260	13	02				340	26	08	260	7	23	350	6	10*	30
31	310	15	06				090	4	02	310	13	18				250	13	11				320	13	18	31
MONTHLY MAX	340	21	12	310	50G	08	340	35	08	290	56	24	330	31	16	330	40	01	310	35	24	310	28	21	MAX
AVE		06			17			15			24			17			16			12			10		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
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CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1975-76

MINIMUM HOURLY WINDS - MPH

DAY	OCT DIR	OCT SPD	OCT HR	NOV DIR	NOV SPD	NOV HR	DEC DIR	DEC SPD	DEC HR	JAN DIR	JAN SPD	JAN HR	FEB DIR	FEB SPD	FEB HR	MAR DIR	MAR SPD	MAR HR	APR DIR	APR SPD	APR HR	MAY DIR	MAY SPD	MAY HR	DAY
1	M	M		110	1	04	300	31	18	120	5	02	320	29	08	230	15	21	230	12	17	320	12	07*	1
2	M	M		010	10	09	300	18	02	340	15	01	320	38	20	VAR	10	07*	280	5	19	270	7	18	2
3	M	M		310	10	23	260	8	17	310	25	19	160	10	18	VAR	5	23	VAR	5	19	310	5	06	3
4	M	M		VAR	1	24	320	14	15	300	29	07	150	19	01	100	3	09*	330	5	20	290	15	02	4
5	M	M		310	3	01	320	11	11	270	14	22	VAR	3	14	330	21	21	090	8	01*	VAR	11	14	5
6	M	M		330	16	01	310	32	03	340	20	21	350	11	05	260	2	12	M	M		M	M		6
7	M	M		270	19	21	320	33	10	320	17	02	300	24	01	020	3	21	360	8	24	M	M		7
8	M	M		340	9	11	340	25	23	290	21	14	320	29	17	060	7	03	360	5	02	VAR	4	19	8
9	M	M		330	7	01	330	15	07	270	19	17	240	19	12	330	20	03	240	15	02	340	7	23	9
10	M	M		290	21	22	310	26	24	340	22	18	350	15	23	270	6	18	VAR	9	20	340	5	04	10
11	M	M		310	35	01	270	10	20	340	14	06	340	15	01	330	14	21	130	7	04	280	22	15	11
12	M	M		320	27	08	310	13	03	280	21	14	300	27	17	310	14	09	130	11	19	330	32	15	12
13	M	M		310	20	16	180	5	12	330	18	17	310	5	13	330	25	18	210	6	03	340	24	13	13
14	M	M		330	14	21	VAR	5	12	300	36	01	300	11	08	310	14	18	190	7	09	300	10	20	14
15	M	M		350	18	01	320	32	01	310	40	09	VAR	2	12	320	24	24	VAR	7	13	140	3	24	15
16	M	M		250	12	18	280	34	09	320	15	24	320	19	08	330	20	24	340	10	23	VAR	2	07	16
17	360	10	11	140	9	19	350	25	23	340	15	01	310	29	24	340	21	04	VAR	4	15	310	15	19	17
18	330	13	12	VAR	4	06	VAR	2	13	350	13	21	310	24	01	270	17	18	VAR	3	20	VAR	5	16	18
19	350	10	10	010	9	10	350	8	23	340	15	03	VAR	7	21	290	23	12	360	10	09	360	7	11	19
20	350	17	22	VAR	4	23	200	2	17	340	15	24	090	13	11	310	20	21	340	20	05	130	5	15	20
21	320	15	10	VAR	2	07	340	8	23	340	15	17	350	16	18	300	32	06	300	21	18	VAR	5	08*	21
22	190	10	18	340	15	10	350	6	15	350	16	02	340	22	03	280	17	17	270	11	07	M	M		22
23	350	6	21	330	22	09	250	8	04	290	20	24	290	22	12	280	29	22	320	11	10	M	M		23
24	320	7	02	320	28	01	340	10	02	260	10	11	270	17	12	280	24	04	280	17	24	VAR	7	19	24
25	310	26	01	010	12	07	340	12	09	340	20	20	280	21	20	VAR	14	15	VAR	7	08	290	12	05	25
26	270	26	20	300	25	15	350	11	11	320	24	01	290	24	22	330	16	08	160	10	01	VAR	4	12	26
27	170	9	08	240	9	18	330	19	24	340	23	21	270	11	18	230	12	21	VAR	8	20	VAR	3	09	27
28	320	16	19	250	13	02	350	11	10	340	14	13*	290	27	08	VAR	4	22	320	4	23	VAR	6	21	28
29	260	13	11	270	4	03	350	12	01	340	14	18	240	21	22	VAR	2	02	VAR	1	22	VAR	3	24	29
30	290	9	18	290	34	23*	VAR	8	23	300	32	01				330	11	01	VAR	3	03	VAR	3	13*	30
31	130	7	08				030	2	14	330	22	14				310	11	19				320	11	23	31
MONTHLY MAX	310	26	01	310	35	01	280	34	09	310	40	09	320	38	20	300	32	06	300	21	18	330	32	15	MAX
AVE		13			14			15			19			18			15			09			09		AVE

G INDICATES GUSTINESS, DEVIATIONS FROM MEAN HOURLY SPEED FREQUENTLY EXCEEDED 15 MPH
M = MISSING DATA

VAR = VARIABLE DIRECTION
HR = WIND DATA ARE FOR THE HOUR ENDING AT TIME SPECIFIED
* = LESS THAN 08 HOURS OF MISSING DATA FOR DAY

Daily Peak Wind Gusts

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1969-70

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		M	M	M	090	36	0051	360	36	2155	310	85	0840	290	45	0712	310	84	2037	M	M		1
2	M	M		M	M	M	090	21	0307	360	52	1654	310	84	1625	310	62	1719	310	71	0039	M	M		2
3	M	M		M	M	M	110	28	2010	340	96	1030	310	80	0127	290	50	1239	310	32	1555	M	M		3
4	M	M		M	M	M	340	51	1510	290	70	0044	290	82	0030	310	56	0700	310	56	1937	M	M		4
5	M	M		340	43	0038	360	33	2359	340	58	1355	310	71	1223	290	50	0026	310	67	0849	M	M		5
6	M	M		360	38	1550	340	45	1917	310	60	2244	310	58	0544	340	65	1951	340	35	0029	M	M		6
7	M	M		290	60	2309	340	46	1925	310	76	0541	310	44	0542	360	50	0127	310	60	2214	M	M		7
8	M	M		310	63	0105	310	59	1332	270	64	0022	340	43	1325	270	55	2337	310	65	1158	M	M		8
9	M	M		290	51	2355	340	43	0300	310	74	1705	340	27	0715	290	69	1104	310	27	2306	M	M		9
10	M	M		290	61	0210	340	78	1254	310	84	0446	310	45	1455	130	35	1243	290	65	1714	M	M		10
11	M	M		310	68	2158	310	72	1245	310	60	0117	310	46	2321	360	27	1317	310	64	2218	M	M		11
12	M	M		310	84	1305	310	78	0035	310	50	0250	310	60	1126	310	67	2302	310	56	0247	M	M		12
13	M	M		310	83	0458	310	73	0015	310	66	0908	310	56	1623	310	82	0108	110	50	2033	M	M		13
14	M	M		340	78	0125	310	48	0248	310	56	1334	310	45	0809	310	66	0400	160	71	1426	M	M		14
15	M	M		310	54	2335	310	46	2230	310	40	0030	340	65	2332	310	40	0503	310	55	0155	M	M		15
16	M	M		220	62	0348	310	52	0020	290	56	2122	310	80	0925	310	55	2338	090	40	1642	M	M		16
17	M	M		310	61	1511	310	58	0045	310	73	0804	270	74	1217	310	52	0315	130	56	1140	M	M		17
18	M	M		350	56	1549	310	34	0603	290	62	1210	310	60	0437	360	59	0350	310	77	2354	M	M		18
19	M	M		310	83	1929	290	53	2012	270	96	0950	360	35	1545	360	32	1413	310	81	0140	M	M		19
20	M	M		360	58	0512	310	100	1145	310	83	0718	340	35	0120	310	35	0458	310	70	0628	M	M		20
21	M	M		310	42	1323	270	88	2340	310	88	0430	360	26	0907	310	60	1312	270	50	0027	M	M		21
22	M	M		340	32	0146	310	94	0602	270	100	1743	110	45	1937	310	75	1042	310	58	0558	M	M		22
23	M	M		360	30	2205	290	78	0058	290	76	0248	270	20	0415	310	100	1435	310	44	2028	M	M		23
24	M	M		310	47	1257	310	82	1922	270	90	1625	110	20	0938	310	109	0949	290	57	2348	M	M		24
25	M	M		360	46	1212	310	71	1341	270	82	0118	310	50	2133	020	83	0800	310	71	0351	M	M		25
26	M	M		310	52	0118	290	69	0729	220	75	2321	310	56	2058	340	38	0011	270	50	0122	M	M		26
27	M	M		360	16	2008	110	28	0720	270	82	2140	310	46	0002	340	40	2145	180	55	1844	M	M		27
28	M	M		360	13	0854	130	22	0147	310	75	1151	310	63	0208	360	40	0201	270	47	0742	M	M		28
29	M	M		360	26	1748	360	34	1727	310	74	0939				090	48	2154	290	30	0059	M	M		29
30	M	M		090	31	2354	360	46	1427	310	58	0020				090	60	0252	360	26	0405	M	M		30
31	M	M					360	45	1148	310	58	2355				110	31	1708				M	M		31
MONTH MAX				310	84	1305	310	100	1145	270	100	1743	310	85	0840	310	109	0949	310	84	2037				MAX
AVE					51			55			70			54			56			56				AVE

YEARLY MAX -- 310 109 MPH ON MAR 24 AT 0949 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1970-71

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		M	M	M	270	70	0305	270	48	0335	290	32	0119	090	46	1850	290	57	1943	M	M		1
2	M	M		M	M	M	270	91	2255	090	64	2338	250	40	1845	290	46	1545	290	47	1106	M	M		2
3	M	M		M	M	M	270	94	0914	090	59	0918	250	45	0245	290	72	1018	290	62	0435	M	M		3
4	M	M		M	M	M	250	57	0045	310	51	1930	290	120	2341	250	53	1135	290	47	2158	M	M		4
5	M	M		M	M	M	290	52	1757	310	37	1500	290	90	0050	250	45	0149	310	48	0145	M	M		5
6	M	M		M	M	M	290	51	2358	310	38	0942	310	70	1319	290	71	1436	250	30	2342	M	M		6
7	M	M		M	M	M	290	62	0321	310	42	2336	310	85	1430	290	80	1015	290	46	2318	M	M		7
8	M	M		M	M	M	290	65	0029	290	102	0631	310	76	0443	290	45	0602	290	59	0104	M	M		8
9	M	M		M	M	M	220	50	1051	290	108	0631	290	67	2244	290	56	1940	270	46	2351	M	M		9
10	M	M		M	M	M	340	43	0651	270	120	1047	290	120	1538	290	66	0748	250	55	0040	M	M		10
11	M	M		M	M	M	290	64	2339	270	73	0638	290	98	0305	290	56	0322	250	66	0320	M	M		11
12	M	M		M	M	M	290	57	1148	220	85	1205	310	54	0645	290	63	0917	270	62	0652	M	M		12
13	M	M		310	34	2208	290	45	0719	270	75	0547	310	70	1815	290	66	0555	110	26	1511	M	M		13
14	M	M		340	36	1249	270	40	0731	290	86	2317	310	65	0318	290	92	1944	270	33	0350	M	M		14
15	M	M		290	45	2355	310	60	1032	270	93	2145	270	60	1710	290	98	0158	310	35	2236	M	M		15
16	M	M		290	62	0203	250	74	1008	290	73	2110	290	77	1011	290	72	0610	310	30	0332	M	M		16
17	M	M		310	50	0300	250	58	0948	290	80	2343	130	39	2058	220	75	1128	180	40	1455	M	M		17
18	M	M		290	50	0735	270	55	2340	290	70	0134	310	61	1820	290	65	2228	110	53	1205	M	M		18
19	M	M		310	85	0925	270	53	0144	310	67	2210	310	58	0200	290	72	0308	090	70	1048	M	M		19
20	M	M		270	85	1208	290	52	2350	270	90	1218	090	58	0940	310	68	1325	290	62	1910	M	M		20
21	M	M		270	100	1512	290	58	0225	270	73	2325	110	22	0048	290	51	1622	290	60	0348	M	M		21
22	M	M		270	81	0950	290	97	1408	270	85	0525	360	22	0607	270	56	0530	070	20	0929	M	M		22
23	M	M		290	57	1223	310	82	0256	310	66	1938	310	34	1632	270	61	0858	110	30	1205	M	M		23
24	M	M		270	65	2231	290	116	2223	290	94	2158	310	51	2251	290	70	1155	290	42	0353	M	M		24
25	M	M		250	83	0809	310	79	0028	290	102	0205	290	77	0612	290	60	1028	090	35	1454	M	M		25
26	M	M		250	55	0455	290	49	1538	290	75	0440	310	96	0525	220	68	2315	290	41	2230	M	M		26
27	M	M		290	55	0925	290	81	0604	290	60	0934	310	65	0546	250	66	0820	290	65	1020	M	M		27
28	M	M		250	55	1425	290	68	2357	310	75	1930	310	35	1150	290	54	1420	290	35	0238	M	M		28
29	M	M		270	60	1249	250	82	0832	290	75	0440				290	53	0513	310	50	2210	M	M		29
30	M	M		270	107	1946	310	107	0313	290	95	0303				220	62	2308	310	47	0008	M	M		30
31	M	M					270	105	1749	310	75	0002				290	65	2111				M	M		31
ONTH MAX				270	107	1946	290	116	2223	270	120	1047	290	120	2341	290	98	0158	090	70	1048				MAX
AVE					65			68			75			64			64			47				AVE

YEARLY MAX -- 270 120 MPH ON JAN 10 AT 1047 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1971-72

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		270	76	2110	120	21	1450	270	102	2035	260	41	0030	310	71	0332	300	72	2359	M	M		1
2	M	M		280	65	0515	290	25	0955	280	122	0934	280	50	2350	240	86	2338	300	75	0004	M	M		2
3	M	M		300	70	2128	280	44	0313	090	72	1029	290	91	1555	280	111	0842	300	54	0735	M	M		3
4	M	M		290	62	2330	300	21	2338	290	100	2304	290	55	0431	270	90	0427	290	60	0726	M	M		4
5	M	M		270	70	0356	300	69	1728	290	97	0100	290	51	1244	280	81	2130	270	70	2141	M	M		5
6	M	M		290	71	0250	290	66	0829	290	85	0338	300	26	0206	250	115	1413	260	67	0828	M	M		6
7	M	M		290	50	0427	100	40	1100	260	67	2111	330	42	1449	240	95	0115	290	65	0005	M	M		7
8	M	M		290	45	0445	290	36	1211	280	80	2149	320	35	0650	290	72	0635	270	54	2111	M	M		8
9	M	M		290	55	1905	290	51	1304	290	116	1121	280	44	0920	280	49	0425	270	53	0332	M	M		9
10	M	M		290	29	1108	280	55	0342	260	106	0630	M	M	M	280	41	0918	270	64	1232	M	M		10
11	M	M		270	26	0111	300	45	2358	280	127	1639	310	62	2355	260	50	0303	280	58	1113	M	M		11
12	M	M		300	37	0935	290	51	0050	280	105	0007	300	73	0456	290	51	1157	290	70	0820	M	M		12
13	M	M		290	63	0734	250	40	0048	290	117	0613	290	74	1330	270	45	1035	240	36	0018	M	M		13
14	M	M		260	42	0150	290	56	2038	300	95	0636	290	60	1233	300	55	1837	100	27	0156	M	M		14
15	M	M		130	45	1010	270	45	0110	290	78	0001	290	67	0950	290	50	0822	320	45	1628	M	M		15
16	M	M		110	31	0324	300	70	0718	290	61	0229	270	100	1950	290	64	1610	250	40	2353	M	M		16
17	M	M		330	20	0125	290	45	2121	280	95	2326	300	85	0158	290	57	0418	250	55	0051	M	M		17
18	M	M		330	42	2233	290	51	0241	290	102	0502	300	74	0002	260	40	1507	240	55	1355	M	M		18
19	M	M		320	47	0830	300	80	2332	300	74	0215	290	52	0831	240	52	0109	110	50	1225	M	M		19
20	M	M		330	52	0423	300	99	0304	300	52	1738	280	49	1204	290	42	2356	310	50	2123	M	M		20
21	M	M		330	21	2012	260	69	0142	270	91	2325	290	47	0222	280	52	0245	300	55	1142	M	M		21
22	M	M		340	25	2150	260	71	2052	M	M	M	290	60	1006	250	49	0228	280	80	0215	M	M		22
23	M	M		310	60	1922	270	85	1308	M	M	M	270	55	1421	290	57	1905	300	42	0542	M	M		23
24	M	M		290	65	0638	240	74	2214	270	85	0628	280	60	1356	290	57	1039	280	30	0910	M	M		24
25	M	M		290	61	1941	260	87	0345	240	65	1335	300	54	1548	240	57	2132	260	50	1649	M	M		25
26	M	M		290	82	0805	230	59	1200	230	54	1242	270	86	2042	250	65	0750	350	69	1100	M	M		26
27	M	M		290	58	0543	270	50	0735	240	65	0122	280	81	0955	090	40	2347	330	45	0108	M	M		27
28	M	M		300	51	2028	260	49	1221	280	72	2325	270	68	0653	090	46	0348	330	45	1137	M	M		28
29	M	M		280	39	0018	270	73	1301	290	50	0208	230	69	0639	310	26	2245	300	42	0641	M	M		29
30	M	M		300	27	0007	290	80	1944	310	32	0048				310	60	1630	310	55	1620	M	M		30
31	M	M					290	69	2201	280	31	2337				320	63	0717				M	M		31
ONTH MAX				290	82	0805	300	99	0304	280	127	1639	270	100	1950	250	115	1413	280	80	0215				MAX
AVE					50			57			83			61			61			54				AVE

YEARLY MAX -- 280 127 MPH ON JAN 11 AT 1639 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1972-73

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		330	60	2128	320	87	0007	280	36	1212	310	45	1614	330	39	0153	090	52	2315	M	M		1
2	M	M		330	44	0130	290	90	1335	330	41	1827	330	37	0624	310	33	0357	090	65	0030	M	M		2
3	M	M		310	30	1646	290	64	0244	250	40	2005	310	47	2201	310	26	1850	350	44	1430	M	M		3
4	M	M		290	32	1638	260	75	1731	300	40	1213	300	70	0346	150	42	2054	340	40	1450	M	M		4
5	M	M		270	40	0626	270	48	0142	280	60	2348	300	50	0557	310	54	1300	330	45	1623	M	M		5
6	M	M		340	36	0548	270	66	0747	290	56	0023	290	50	2139	310	43	1913	290	61	0951	M	M		6
7	M	M		270	41	1502	250	63	0947	280	50	2315	280	56	0056	300	42	0440	090	74	0843	M	M		7
8	M	M		270	50	0311	260	60	1351	290	50	1345	330	16	0028	090	35	1220	350	68	2355	M	M		8
9	M	M		340	45	0405	260	41	1520	290	45	0110	300	40	2305	150	31	1016	330	66	0133	M	M		9
10	M	M		300	46	0649	270	50	2257	330	53	1338	300	53	0912	360	30	2304	310	53	1004	M	M		10
11	M	M		120	25	2325	260	50	0021	300	61	1930	270	40	0122	320	46	0403	320	19	0015	M	M		11
12	M	M		090	45	1223	310	56	1017	310	86	0127	300	60	0644	160	53	2338	330	30	0534	M	M		12
13	M	M		300	32	2243	280	51	0802	300	99	0557	330	27	0445	140	59	0544	300	35	0135	M	M		13
14	M	M		300	48	0208	320	65	1918	300	49	0104	340	36	1427	320	42	0054	210	50	0955	M	M		14
15	M	M		320	54	1730	300	54	2041	300	46	2335	340	22	0738	320	30	1730	310	47	1752	M	M		15
16	M	M		340	40	0058	320	52	1508	310	55	2222	310	26	0328	310	27	2357	310	58	1701	M	M		16
17	M	M		130	30	1128	290	52	0741	280	58	1711	360	21	0241	310	26	0003	310	80	0150	M	M		17
18	M	M		330	35	1725	320	49	0840	300	79	0447	320	35	2312	290	16	0239	140	47	1525	M	M		18
19	M	M		090	30	2154	310	83	1054	270	53	0655	300	50	1130	310	12	1039	320	84	1818	M	M		19
20	M	M		090	49	1729	330	62	0536	340	33	2335	310	52	0742	140	43	2335	300	75	0354	M	M		20
21	M	M		330	36	1550	300	62	1050	350	40	0115	090	19	2321	160	65	0615	290	31	2333	M	M		21
22	M	M		350	29	0034	310	76	2144	M	M	M	090	53	0933	290	65	0626	310	57	1014	M	M		22
23	M	M		330	21	2357	330	67	0453	360	36	0735	350	33	1552	090	45	1930	280	29	0232	M	M		23
24	M	M		320	76	1838	280	63	1018	360	22	0026	280	27	1551	350	29	1747	250	26	1224	M	M		24
25	M	M		320	73	1101	320	60	0101	310	25	2225	300	60	0652	300	27	2054	300	50	1443	M	M		25
26	M	M		300	130	0710	320	64	1213	090	40	0824	310	43	0347	310	31	0403	350	42	2103	M	M		26
27	M	M		310	102	0118	300	57	0428	340	32	2033	300	35	2358	090	39	0951	280	45	2326	M	M		27
28	M	M		320	70	0508	120	45	2357	300	63	2348	300	37	0002	120	34	1257	300	70	0533	M	M		28
29	M	M		310	105	1720	100	53	0351	270	66	2340				120	35	1010	270	69	0500	M	M		29
30	M	M		310	97	2108	340	70	1005	270	85	0245				330	34	2329	090	38	1615	M	M		30
31	M	M					320	47	0058	280	32	0032				320	50	1606				M	M		31
MONTH MAX				300	130	0710	290	90	1335	300	99	0557	300	70	0346	160	65	0615	320	84	1818				MAX
AVE					52			61			51			41			38			52				AVE

YEARLY MAX -- 300 130 MPH ON NOV 26 AT 0710 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

WINTER 1973-74

DAILY PEAK WIND GUSTS - MPH

DAY	OCT DIR	OCT SPD	OCT HOUR	NOV DIR	NOV SPD	NOV HOUR	DEC DIR	DEC SPD	DEC HOUR	JAN DIR	JAN SPD	JAN HOUR	FEB DIR	FEB SPD	FEB HOUR	MAR DIR	MAR SPD	MAR HOUR	APR DIR	APR SPD	APR HOUR	MAY DIR	MAY SPD	MAY HOUR	DAY
1	M	M		280	96	1018	240	67	2245	280	37	0210	290	63	1756	260	96	0258	260	70	2310	M	M		1
2	M	M		240	50	1355	230	66	0156	310	25	0659	330	75	0320	290	81	2200	330	51	1733	M	M		2
3	M	M		250	62	1520	340	45	2108	270	58	2208	300	70	1720	300	53	0201	340	56	0315	M	M		3
4	M	M		270	76	2338	340	60	0529	270	60	1215	280	97	1142	320	73	2106	300	58	2258	M	M		4
5	M	M		270	82	0058	310	60	0223	270	80	1622	270	45	0012	290	65	1528	300	71	0102	M	M		5
6	M	M		310	95	1943	330	46	1020	290	82	0858	310	40	2248	310	72	0317	300	74	2304	M	M		6
7	M	M		320	78	0125	310	81	2113	280	90	0620	330	50	2301	250	77	2150	320	73	0031	M	M		7
8	M	M		310	74	0940	300	77	1229	270	69	1837	310	60	1715	240	54	0157	290	60	1138	M	M		8
9	M	M		290	51	0001	320	54	1136	280	56	0050	300	69	1546	090	55	1604	120	71	2001	M	M		9
10	M	M		310	53	0704	310	90	1320	290	88	1835	300	72	0032	310	70	2354	350	49	2011	M	M		10
11	M	M		300	55	0652	280	90	2126	290	86	0720	300	62	1448	300	79	0232	320	80	2215	M	M		11
12	M	M		270	94	2112	300	116	0533	290	76	1527	270	69	0715	290	45	2135	290	81	0546	M	M		12
13	M	M		280	80	0003	290	82	2019	290	80	2056	290	55	0431	290	73	1517	320	61	1440	M	M		13
14	M	M		300	88	2128	310	70	2241	310	102	1815	340	30	2219	270	71	1956	320	46	2003	M	M		14
15	M	M		320	61	0008	300	71	0837	310	73	0323	290	70	2313	290	74	1421	330	55	1315	M	M		15
16	M	M		280	74	0736	300	70	0632	310	51	2046	300	58	0422	300	78	0341	290	37	0143	M	M		16
17	M	M		290	65	0141	300	80	0654	290	53	0443	270	50	0142	290	95	0753	300	35	0420	M	M		17
18	M	M		250	55	1220	300	45	0046	310	60	2331	300	57	2151	280	80	0001	120	35	1828	M	M		18
19	M	M		090	55	0822	340	35	2340	300	70	0551	300	55	0142	270	55	2338	220	50	1341	M	M		19
20	M	M		300	68	2352	300	75	1839	310	41	1209	360	37	1715	270	67	0048	310	70	2045	M	M		20
21	M	M		290	73	0318	270	65	2355	310	55	0643	310	58	1500	290	67	0301	310	55	2341	M	M		21
22	M	M		270	60	0430	280	80	0042	330	71	1244	300	69	1759	290	80	0256	320	51	0029	M	M		22
23	M	M		290	64	2359	360	28	0013	330	45	0803	320	77	0202	300	75	1035	160	40	1939	M	M		23
24	M	M		300	66	0054	340	50	1916	320	43	0603	330	50	0115	300	70	0958	280	55	0625	M	M		24
25	M	M		280	57	1910	300	93	0933	280	64	2002	330	50	0657	300	85	0346	260	44	0123	M	M		25
26	M	M		270	57	0150	300	60	2135	300	70	0027	280	65	0145	290	52	0012	260	55	0753	M	M		26
27	M	M		300	100	2110	310	98	1633	350	60	1947	270	90	1520	270	68	0608	270	79	0602	M	M		27
28	M	M		310	78	0048	290	110	2000	320	77	1807	290	74	0103	280	100	1042	210	31	1211	M	M		28
29	M	M		280	77	2232	310	110	0603	300	101	2006				280	90	2357	330	29	1711	M	M		29
30	M	M		290	70	0308	310	80	0341	310	92	1508				290	90	0010	320	30	2031	M	M		30
31	M	M					320	54	0603	290	81	1832				300	68	2258				M	M		31
MONTH MAX				300	100	2110	300	116	0533	310	102	1815	280	97	1142	280	100	1042	290	81	0546				MAX
AVE					70			71			68			61			73			55				AVE

YEARLY MAX -- 300 116 MPH ON DEC 12 AT 0533 HOURS

M = MISSING DATA

CLIMATOLOGICAL SUMMARY
BERTHOUD PASS, COLORADO

MINES PEAK - ELEV. 12,493 FT.

DAILY PEAK WIND GUSTS - MPH

WINTER 1974-75

	OCT			NOV			DEC			JAN			FEB			MAR			APR			MAY			
AY	DIR	SPD	HOUR	DIR	SPD	HOUR	DIR	SPD	HOUR	DIR	SPD	HOUR	DIR	SPD	HOUR	DIR	SPD	HOUR	DIR	SPD	HOUR	DIR	SPD	HOUR	DAY
1	M	M		290	38	0314	310	45	0202	110	35	0848	290	65	1400	310	62	0632	320	54	2339	M	M		1
2	M	M		120	25	1322	320	36	2318	350	56	0851	340	31	2136	290	70	0948	310	70	1504	M	M		2
3	M	M		M	M	M	320	35	2350	310	65	0802	330	33	0652	330	52	0353	260	62	2242	M	M		3
4	M	M		M	M	M	330	40	0821	330	71	2239	280	23	2241	280	64	1857	250	60	0720	M	M		4
5	M	M		130	22	1525	350	35	1718	310	71	1646	340	58	1543	280	75	0123	290	56	0821	M	M		5
6	M	M		340	36	1856	350	50	1458	280	94	0230	310	65	2353	310	79	1346	160	92	2322	M	M		6
7	M	M		330	30	0642	110	40	1544	290	80	0416	310	72	0030	310	52	0318	310	78	2021	M	M		7
8	M	M		100	37	2142	340	28	2007	270	68	1121	280	76	1437	290	55	0010	310	69	0042	M	M		8
9	M	M		320	43	2300	100	29	2350	350	48	1456	300	86	2147	340	41	1319	290	43	0938	M	M		9
10	M	M		340	72	2105	100	26	0003	320	64	2350	320	68	1604	310	40	1118	100	40	2318	M	M		10
11	M	M		300	66	0950	310	85	2351	320	80	1515	320	91	0226	360	26	1240	110	42	1410	M	M		11
12	M	M		280	90	2355	310	96	0045	310	74	2023	290	82	2256	340	30	2238	100	25	1318	M	M		12
13	M	M		300	121	0140	330	56	2012	310	81	1116	280	85	0514	320	40	0946	310	45	2251	M	M		13
14	M	M		300	80	0323	300	70	2032	310	98	1716	110	47	2031	110	36	2329	300	51	0900	M	M		14
15	M	M		300	61	0137	320	71	0453	320	60	1112	120	32	0002	090	35	0049	270	65	0739	M	M		15
16	M	M		320	50	0203	310	81	1702	310	76	0855	320	33	1131	230	40	2222	250	50	0234	M	M		16
17	M	M		320	42	0542	280	60	1257	310	76	2213	100	44	0310	310	56	2252	260	45	0258	M	M		17
18	M	M		280	85	1937	310	65	1624	310	100	1628	310	55	0428	310	66	1110	310	85	2120	M	M		18
19	M	M		300	65	0137	310	82	0600	320	64	1213	310	65	1255	310	84	0730	300	70	0357	M	M		19
20	M	M		290	80	0450	320	86	1745	300	90	0638	290	76	1625	290	70	0615	300	40	0938	M	M		20
21	M	M		300	55	0001	280	90	2203	090	58	0530	300	45	0226	300	67	1127	160	30	1220	M	M		21
22	M	M		260	41	0240	280	82	0121	330	54	0617	310	41	1616	250	76	0440	290	55	1348	M	M		22
23	M	M		350	50	0733	110	64	1552	310	70	2214	350	42	0758	300	90	1954	280	44	0021	M	M		23
24	M	M		320	50	1438	360	41	1704	310	122	1535	320	88	1445	330	96	0430	240	47	2313	M	M		24
25	M	M		310	82	2132	330	49	0346	310	124	0801	310	55	1225	150	50	2225	160	70	2022	M	M		25
26	M	M		310	70	1841	290	32	0030	280	94	1130	310	65	2031	090	53	0255	160	73	0819	M	M		26
27	M	M		290	59	1132	330	50	0454	260	45	0802	310	100	0234	360	37	1501	310	100	2254	M	M		27
28	M	M		100	45	0831	270	34	0521	270	74	1157	310	81	1214	350	46	1106	330	90	0046	M	M		28
29	M	M		340	40	1559	280	36	1650	260	70	1309				320	52	2330	320	45	2156	M	M		29
30	M	M		330	40	1445	350	35	0751	250	50	1235				300	65	2017	290	40	1530	M	M		30
31	M	M					350	40	2007	290	53	0617				300	65	0556				M	M		31
NTH AX				300	121	0140	310	96	0045	310	124	0801	310	100	0234	330	96	0430	310	100	2254				MAX
VE					56			54			73			61			57			58					AVE

YEARLY MAX -- 310 124 MPH ON JAN 25 AT 0801 HOURS

= MISSING DATA

Berthoud Pass, Colorado — Station Q-12 Park

Mean Annual Hourly Precipitation

BERTHOUD PASS, COLORADO - MEAN ANNUAL HOURLY PRECIPITATION BY DAYS
STATION Q-12 PARK, FOR MONTH OF NOV.

DAY	HOURS AM 1	2	3	4	5	6	7	8	9	10	11	12	HOURS PM 13	14	15	16	17	18	19	20	21	22	23	24	DAY AVG.
1	.009	.008	.008	.008	.005	.005	.004	.008	.013	.006	.009	.003	.003	.001	.002	.004	.003	.006	.003	.003	.006	.004	.006	.007	.005
2	.005	.010	.008	.013	.013	.008	.004	.006	.006	.006	.008	.007	.003	.002	.001	.004	.004	.006	.006	.009	.004	.006	.008	.004	.006
3	.001	.004	.001	.001	.001	.001	.001	.002	.002	.002	.002	.002	.001	.001	.004	.005	.002	.001	.002	.001	.001	.000	.003	.003	.002
4	.004	.007	.004	.005	.006	.011	.008	.004	.002	.011	.004	.002	.001	.000	.003	.002	.001	.001	.000	.000	.000	.000	.000	.000	.003
5	.001	.000	.000	.001	.009	.006	.004	.001	.001	.001	.001	.003	.001	.003	.003	.000	.003	.000	.000	.000	.000	.000	.000	.000	.001
6	.000	.000	.001	.000	.002	.001	.000	.000	.001	.000	.001	.000	.001	.001	.001	.000	.001	.001	.001	.000	.000	.000	.000	.001	.000
7	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.001	.000	.000	.001	.001	.009	.003	.001	.004	.002	.003	.002	.002	.001
8	.002	.003	.003	.003	.005	.004	.003	.002	.003	.004	.002	.002	.004	.004	.001	.003	.008	.018	.004	.006	.002	.007	.004	.002	.004
9	.001	.001	.002	.004	.002	.001	.004	.009	.006	.004	.005	.006	.002	.003	.002	.003	.002	.001	.001	.002	.005	.002	.004	.001	.003
10	.002	.001	.002	.004	.001	.003	.003	.003	.002	.001	.002	.002	.003	.003	.002	.004	.004	.003	.009	.008	.006	.006	.005	.004	.003
11	.006	.004	.004	.004	.002	.001	.002	.004	.003	.002	.003	.001	.000	.001	.003	.002	.002	.002	.004	.006	.006	.007	.008	.004	.003
12	.007	.003	.006	.004	.007	.007	.007	.003	.005	.005	.003	.004	.002	.003	.003	.002	.007	.004	.002	.007	.005	.005	.007	.003	.005
13	.004	.002	.006	.004	.006	.002	.002	.011	.006	.004	.003	.003	.003	.003	.006	.011	.003	.003	.003	.003	.003	.001	.005	.003	.004
14	.004	.004	.004	.003	.004	.001	.002	.002	.002	.001	.003	.001	.004	.002	.004	.009	.006	.005	.007	.010	.006	.003	.005	.005	.004
15	.004	.002	.003	.001	.000	.001	.005	.003	.005	.005	.002	.004	.005	.004	.005	.004	.003	.004	.003	.003	.002	.001	.001	.001	.003
16	.002	.003	.003	.002	.005	.004	.004	.004	.002	.005	.005	.005	.003	.004	.005	.006	.007	.003	.005	.004	.003	.003	.005	.002	.004
17	.002	.001	.002	.002	.001	.002	.001	.006	.003	.004	.002	.002	.002	.004	.006	.004	.002	.004	.002	.002	.002	.005	.006	.006	.003
18	.003	.004	.002	.001	.002	.005	.006	.003	.002	.004	.005	.002	.002	.003	.004	.004	.003	.002	.002	.003	.005	.004	.003	.007	.003
19	.003	.003	.005	.004	.005	.004	.003	.003	.002	.003	.003	.005	.007	.005	.003	.002	.002	.002	.001	.001	.003	.001	.001	.002	.003
20	.001	.001	.001	.003	.002	.003	.002	.001	.001	.001	.003	.003	.005	.005	.002	.002	.001	.002	.001	.001	.001	.001	.002	.002	.002
21	.002	.003	.004	.002	.003	.003	.002	.003	.001	.008	.000	.002	.003	.003	.003	.009	.001	.005	.006	.008	.007	.008	.009	.004	.004
22	.002	.005	.005	.005	.003	.005	.004	.003	.004	.004	.004	.004	.003	.003	.003	.004	.003	.003	.005	.002	.005	.003	.002	.004	.003
23	.003	.002	.004	.004	.006	.005	.008	.006	.006	.007	.006	.008	.006	.006	.003	.004	.002	.002	.001	.001	.001	.001	.001	.001	.004
24	.001	.003	.004	.002	.002	.002	.004	.002	.004	.005	.002	.001	.001	.000	.003	.002	.002	.003	.001	.004	.003	.002	.004	.005	.002
25	.006	.004	.002	.002	.011	.003	.005	.004	.005	.007	.005	.005	.005	.005	.004	.001	.004	.008	.016	.006	.006	.006	.006	.005	.005
26	.004	.006	.003	.007	.004	.005	.003	.005	.007	.005	.008	.008	.007	.012	.008	.007	.007	.007	.010	.007	.007	.008	.006	.009	.006
27	.007	.006	.006	.005	.006	.010	.009	.004	.005	.004	.006	.004	.012	.010	.004	.004	.004	.006	.005	.007	.005	.004	.008	.003	.006
28	.004	.002	.003	.003	.001	.004	.004	.003	.002	.001	.001	.000	.003	.002	.002	.004	.002	.004	.006	.002	.002	.002	.001	.001	.002
29	.001	.001	.001	.001	.001	.000	.002	.001	.001	.004	.001	.002	.001	.000	.001	.001	.001	.000	.000	.001	.001	.001	.001	.001	.001
30	.001	.001	.001	.001	.001	.002	.002	.001	.001	.001	.000	.000	.000	.000	.000	.000	.001	.000	.001	.001	.000	.001	.001	.003	.001
AVG.	.003	.003	.003	.003	.004	.004	.004	.003	.003	.004	.003	.003	.003	.003	.003	.003	.003	.003	.004	.004	.003	.003	.004	.003	.003

BERTHOUD PASS, COLORADO - MEAN ANNUAL HOURLY PRECIPITATION BY DAYS
STATION Q-12 PARK, FOR MONTH OF DEC.

DAY	HOURS AM 1	2	3	4	5	6	7	8	9	10	11	12	HOURS PM 13	14	15	16	17	18	19	20	21	22	23	24	DAY AVG.
1	.003	.000	.005	.003	.000	.002	.001	.001	.000	.003	.000	.001	.003	.005	.003	.006	.005	.005	.002	.001	.002	.004	.002	.002	.002
2	.001	.001	.001	.001	.000	.001	.003	.001	.001	.000	.002	.002	.002	.001	.003	.000	.000	.004	.002	.000	.001	.001	.000	.000	.001
3	.001	.001	.003	.002	.003	.002	.002	.000	.000	.002	.002	.002	.001	.001	.001	.003	.003	.002	.001	.005	.006	.004	.006	.007	.002
4	.003	.009	.007	.006	.007	.004	.005	.002	.004	.007	.002	.006	.005	.009	.006	.003	.002	.001	.007	.008	.006	.004	.009	.002	.005
5	.002	.001	.001	.000	.002	.001	.002	.002	.001	.002	.002	.003	.002	.004	.002	.006	.004	.004	.003	.007	.003	.006	.004	.004	.003
6	.002	.010	.003	.004	.004	.005	.006	.008	.006	.002	.003	.003	.003	.004	.006	.005	.001	.004	.000	.006	.002	.005	.005	.004	.004
7	.004	.002	.002	.006	.008	.005	.006	.009	.007	.011	.002	.003	.003	.004	.006	.005	.003	.004	.002	.005	.004	.003	.003	.003	.005
8	.006	.010	.005	.004	.005	.006	.002	.011	.003	.011	.003	.004	.005	.001	.000	.003	.005	.005	.004	.001	.001	.001	.001	.002	.004
9	.004	.002	.003	.003	.002	.001	.002	.002	.004	.004	.003	.005	.005	.004	.003	.002	.001	.003	.002	.001	.003	.007	.008	.007	.003
10	.005	.002	.002	.001	.006	.005	.002	.003	.003	.001	.001	.001	.002	.002	.003	.003	.002	.003	.005	.004	.003	.004	.002	.001	.003
11	.002	.003	.004	.004	.005	.006	.005	.005	.004	.003	.003	.005	.006	.007	.010	.003	.005	.001	.002	.008	.006	.005	.005	.006	.005
12	.005	.004	.005	.002	.006	.002	.003	.006	.000	.003	.002	.001	.002	.001	.001	.001	.000	.001	.001	.001	.001	.003	.003	.004	.003
13	.005	.002	.003	.003	.003	.004	.003	.001	.003	.002	.002	.001	.009	.004	.001	.004	.005	.002	.001	.005	.004	.004	.004	.004	.003
14	.005	.003	.001	.006	.003	.002	.002	.001	.003	.000	.002	.002	.003	.002	.002	.002	.002	.000	.000	.002	.000	.001	.002	.004	.002
15	.005	.003	.002	.004	.004	.002	.003	.003	.005	.005	.002	.003	.002	.001	.000	.000	.000	.000	.000	.000	.000	.000	.001	.002	.002
16	.001	.002	.001	.001	.001	.004	.007	.010	.004	.006	.002	.002	.002	.003	.000	.001	.002	.003	.005	.002	.000	.000	.001	.000	.003
17	.001	.004	.004	.002	.002	.003	.002	.002	.000	.002	.002	.001	.001	.002	.003	.003	.004	.004	.004	.005	.008	.001	.008	.007	.003
18	.009	.007	.006	.005	.005	.004	.001	.006	.007	.005	.007	.003	.004	.003	.002	.001	.000	.000	.000	.000	.000	.001	.004	.001	.003
19	.004	.004	.004	.006	.004	.003	.002	.001	.002	.001	.001	.001	.002	.000	.001	.005	.002	.003	.003	.005	.003	.008	.003	.003	.003
20	.001	.003	.002	.002	.003	.005	.007	.003	.008	.005	.008	.005	.005	.002	.003	.004	.004	.003	.003	.003	.002	.002	.001	.000	.004
21	.002	.004	.004	.002	.003	.003	.008	.003	.002	.006	.008	.004	.004	.006	.006	.002	.003	.001	.006	.003	.003	.003	.004	.002	.004
22	.002	.002	.004	.008	.009	.011	.010	.007	.006	.010	.010	.007	.004	.007	.004	.005	.003	.003	.008	.004	.006	.005	.003	.003	.006
23	.002	.002	.002	.001	.003	.001	.002	.002	.002	.002	.003	.003	.004	.004	.009	.007	.009	.008	.007	.006	.005	.007	.006	.004	.004
24	.003	.006	.003	.003	.001	.001	.005	.003	.004	.004	.005	.004	.005	.004	.007	.005	.007	.003	.003	.001	.001	.001	.002	.003	.004
25	.001	.003	.007	.003	.002	.007	.003	.002	.002	.002	.003	.003	.008	.002	.005	.002	.006	.001	.002	.002	.002	.001	.002	.004	.003
26	.004	.004	.002	.004	.005	.003	.003	.005	.005	.005	.006	.009	.011	.005	.003	.005	.007	.003	.006	.005	.007	.006	.005	.003	.005
27	.004	.007	.003	.009	.005	.008	.008	.005	.008	.007	.007	.004	.005	.004	.003	.003	.002	.004	.004	.003	.004	.003	.004	.004	.005
28	.002	.004	.004	.004	.005	.006	.003	.006	.003	.005	.002	.004	.004	.007	.007	.003	.004	.005	.005	.003	.008	.003	.003	.003	.004
29	.008	.007	.005	.007	.004	.005	.007	.014	.010	.006	.005	.004	.009	.011	.012	.008	.005	.008	.008	.012	.007	.005	.005	.007	.007
30	.008	.005	.008	.011	.007	.009	.011	.007	.008	.010	.008	.007	.011	.008	.003	.003	.005	.006	.005	.003	.005	.001	.002	.003	.006
31	.002	.002	.000	.000	.002	.001	.002	.002	.004	.003	.002	.003	.005	.003	.004	.003	.002	.005	.000	.002	.004	.000	.003	.005	.002
AVG.	.003	.004	.003	.004	.004	.004	.004	.004	.004	.004	.004	.003	.004	.004	.004	.003	.003	.003	.003	.004	.004	.003	.004	.003	.004

BERTHOUD PASS, COLORADO - MEAN ANNUAL HOURLY PRECIPITATION BY DAYS
STATION Q-12 PARK, FOR MONTH OF JAN.

	HOURS AM												HOURS PM												DAY
DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG.
1	.006	.003	.003	.006	.003	.004	.004	.004	.002	.003	.003	.002	.002	.001	.003	.003	.004	.003	.002	.002	.002	.003	.004	.001	.003
2	.004	.004	.001	.003	.003	.002	.000	.002	.001	.002	.003	.002	.001	.002	.003	.003	.007	.005	.004	.003	.006	.005	.006	.004	.003
3	.004	.003	.003	.003	.002	.003	.003	.001	.000	.001	.001	.002	.006	.004	.002	.001	.001	.000	.001	.001	.001	.000	.002	.002	.002
4	.002	.003	.003	.004	.003	.002	.003	.003	.002	.003	.003	.002	.003	.001	.004	.003	.001	.002	.002	.003	.005	.001	.003	.003	.003
5	.003	.001	.002	.001	.001	.004	.003	.002	.007	.005	.002	.002	.001	.002	.002	.001	.003	.002	.002	.004	.007	.006	.005	.004	.003
6	.008	.006	.004	.007	.007	.005	.003	.001	.003	.002	.001	.001	.001	.003	.003	.002	.003	.003	.003	.003	.002	.005	.006	.004	.004
7	.003	.001	.001	.003	.003	.003	.003	.005	.005	.003	.004	.002	.004	.006	.003	.003	.003	.003	.003	.003	.003	.003	.007	.010	.003
8	.008	.005	.003	.003	.005	.004	.006	.004	.010	.005	.005	.004	.008	.007	.008	.008	.005	.006	.006	.003	.002	.003	.003	.000	.005
9	.000	.002	.002	.003	.005	.005	.009	.009	.003	.004	.005	.004	.004	.005	.003	.002	.002	.003	.002	.003	.003	.003	.002	.002	.003
10	.003	.002	.002	.005	.003	.003	.002	.003	.006	.008	.005	.004	.003	.005	.002	.003	.005	.003	.004	.001	.003	.001	.003	.003	.003
11	.003	.003	.003	.002	.003	.002	.003	.000	.001	.001	.004	.003	.003	.002	.004	.004	.003	.004	.005	.004	.004	.006	.005	.005	.003
12	.003	.003	.003	.000	.002	.001	.004	.002	.004	.005	.004	.005	.003	.007	.010	.009	.004	.005	.003	.004	.003	.002	.003	.003	.004
13	.002	.002	.004	.002	.003	.003	.003	.001	.004	.008	.003	.003	.004	.008	.008	.008	.007	.005	.004	.007	.005	.003	.005	.005	.004
14	.007	.008	.008	.014	.006	.009	.010	.007	.007	.007	.003	.005	.004	.002	.004	.005	.006	.004	.008	.004	.006	.005	.005	.003	.006
15	.005	.004	.004	.002	.006	.004	.004	.003	.002	.006	.001	.001	.006	.003	.004	.005	.001	.001	.000	.004	.003	.001	.003	.002	.003
16	.002	.003	.003	.002	.001	.000	.001	.003	.003	.005	.004	.004	.005	.002	.001	.003	.003	.003	.005	.002	.001	.005	.005	.005	.003
17	.004	.009	.007	.007	.004	.003	.007	.004	.004	.006	.005	.004	.004	.003	.003	.004	.002	.004	.003	.003	.002	.005	.005	.005	.004
18	.005	.008	.010	.005	.006	.004	.006	.005	.004	.004	.011	.005	.005	.005	.005	.007	.009	.007	.011	.007	.010	.007	.004	.005	.006
19	.005	.002	.001	.003	.003	.005	.009	.005	.005	.005	.001	.004	.002	.004	.003	.002	.001	.000	.002	.003	.000	.001	.001	.004	.003
20	.009	.005	.006	.006	.005	.005	.003	.003	.005	.007	.005	.005	.001	.008	.005	.003	.005	.002	.005	.005	.003	.004	.007	.006	.005
21	.004	.005	.008	.005	.009	.009	.004	.004	.003	.003	.000	.001	.003	.003	.004	.003	.000	.003	.003	.004	.004	.001	.002	.001	.003
22	.003	.003	.003	.005	.005	.005	.005	.005	.007	.005	.005	.004	.003	.006	.006	.005	.003	.002	.002	.001	.001	.003	.002	.002	.004
23	.003	.003	.001	.002	.002	.004	.004	.001	.003	.002	.002	.004	.001	.003	.002	.004	.001	.002	.003	.006	.002	.002	.006	.006	.003
24	.003	.005	.002	.002	.004	.005	.005	.006	.006	.003	.003	.004	.004	.005	.004	.005	.006	.003	.004	.006	.011	.008	.007	.006	.005
25	.005	.005	.004	.005	.007	.009	.008	.007	.004	.007	.007	.010	.007	.008	.007	.012	.008	.008	.009	.010	.008	.007	.008	.006	.007
26	.018	.012	.009	.007	.015	.007	.004	.012	.005	.004	.003	.003	.003	.002	.003	.003	.001	.004	.006	.009	.006	.008	.004	.005	.006
27	.001	.002	.002	.007	.010	.007	.013	.010	.005	.006	.005	.013	.010	.002	.002	.005	.009	.005	.014	.010	.013	.007	.005	.007	.007
28	.004	.006	.005	.005	.003	.006	.003	.004	.003	.007	.005	.005	.003	.002	.003	.005	.004	.005	.004	.002	.001	.002	.004	.001	.004
29	.003	.003	.003	.003	.001	.003	.001	.002	.005	.005	.007	.005	.004	.003	.005	.004	.003	.002	.003	.006	.005	.002	.003	.002	.003
30	.002	.003	.001	.002	.002	.004	.002	.003	.005	.003	.005	.006	.001	.003	.004	.001	.007	.004	.003	.002	.001	.001	.000	.001	.003
31	.001	.002	.002	.002	.006	.005	.005	.004	.006	.007	.005	.007	.005	.004	.003	.003	.004	.006	.013	.005	.010	.005	.005	.009	.005
AVG.	.004	.004	.004	.004	.004	.004	.004	.004	.004	.005	.004	.004	.004	.004	.004	.004	.004	.003	.004	.004	.004	.004	.004	.004	.004

BERTHOUD PASS, COLORADO - MEAN ANNUAL HOURLY PRECIPITATION BY DAYS
STATION Q-12 PARK, FOR MONTH OF FEB.

	HOURS AM												HOURS PM												DAY
DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG.
1	.006	.004	.003	.002	.001	.003	.005	.004	.005	.007	.005	.004	.004	.008	.006	.007	.007	.004	.004	.004	.003	.004	.005	.005	.005
2	.004	.003	.003	.001	.001	.004	.003	.004	.003	.004	.002	.000	.000	.003	.002	.002	.004	.001	.002	.006	.006	.003	.003	.003	.003
3	.003	.003	.003	.001	.002	.001	.002	.000	.000	.001	.002	.003	.003	.003	.003	.004	.003	.003	.002	.001	.002	.003	.003	.002	.002
4	.002	.003	.006	.005	.004	.003	.002	.001	.002	.000	.000	.001	.002	.002	.003	.002	.003	.001	.007	.003	.007	.006	.005	.005	.003
5	.003	.003	.003	.005	.007	.009	.004	.002	.003	.008	.009	.006	.003	.006	.006	.003	.003	.002	.002	.001	.003	.002	.003	.003	.004
6	.004	.004	.003	.003	.003	.003	.006	.008	.011	.007	.005	.004	.003	.002	.001	.003	.003	.001	.001	.002	.004	.002	.002	.002	.004
7	.002	.003	.003	.002	.002	.002	.003	.005	.002	.007	.006	.005	.007	.003	.005	.003	.002	.001	.002	.000	.002	.003	.003	.001	.003
8	.003	.004	.003	.002	.011	.009	.007	.005	.010	.008	.003	.008	.003	.005	.004	.009	.001	.002	.003	.005	.003	.005	.006	.003	.005
9	.002	.003	.009	.002	.003	.001	.003	.003	.006	.003	.003	.003	.003	.003	.003	.003	.003	.003	.004	.003	.002	.004	.001	.002	.003
10	.002	.001	.002	.003	.001	.003	.003	.003	.002	.002	.003	.005	.006	.007	.007	.004	.003	.003	.003	.004	.004	.003	.002	.003	.003
11	.007	.007	.003	.001	.004	.002	.003	.001	.000	.003	.002	.001	.001	.002	.002	.001	.001	.002	.001	.000	.001	.002	.002	.001	.002
12	.003	.002	.002	.000	.001	.002	.000	.006	.007	.004	.004	.007	.007	.005	.007	.005	.007	.010	.002	.005	.005	.003	.006	.003	.004
13	.002	.004	.004	.003	.000	.000	.001	.003	.006	.004	.002	.004	.003	.000	.000	.003	.002	.004	.004	.000	.003	.003	.003	.003	.003
14	.004	.004	.005	.005	.003	.005	.004	.007	.007	.008	.005	.009	.005	.007	.002	.002	.003	.003	.006	.008	.005	.010	.009	.008	.006
15	.005	.006	.004	.005	.003	.004	.003	.006	.007	.007	.017	.004	.006	.008	.004	.004	.003	.003	.001	.002	.001	.003	.001	.005	.005
16	.002	.004	.008	.005	.006	.005	.003	.002	.010	.006	.005	.003	.009	.004	.009	.003	.002	.002	.005	.001	.003	.009	.003	.006	.005
17	.004	.006	.003	.003	.008	.005	.004	.005	.006	.004	.009	.003	.005	.008	.005	.005	.001	.008	.010	.006	.013	.011	.008	.005	.006
18	.006	.006	.004	.004	.003	.003	.004	.002	.004	.006	.004	.006	.007	.007	.007	.006	.008	.005	.005	.001	.003	.005	.006	.010	.005
19	.004	.001	.002	.004	.003	.004	.004	.006	.005	.005	.005	.005	.006	.006	.003	.003	.009	.008	.007	.008	.002	.008	.005	.003	.005
20	.003	.003	.002	.004	.007	.006	.007	.011	.010	.007	.010	.008	.006	.005	.006	.005	.004	.005	.005	.007	.002	.003	.004	.004	.005
21	.003	.003	.006	.003	.001	.004	.005	.003	.005	.002	.002	.002	.001	.001	.000	.003	.002	.004	.004	.005	.004	.004	.002	.003	.003
22	.002	.003	.002	.003	.002	.003	.008	.008	.004	.001	.001	.003	.002	.004	.005	.007	.005	.010	.004	.004	.007	.006	.003	.001	.004
23	.004	.002	.004	.003	.006	.004	.003	.004	.003	.006	.009	.007	.005	.006	.003	.002	.003	.004	.002	.008	.005	.003	.003	.003	.004
24	.005	.004	.005	.008	.003	.003	.003	.001	.006	.002	.004	.002	.003	.004	.004	.002	.002	.005	.004	.001	.001	.002	.002	.001	.003
25	.002	.004	.008	.005	.003	.003	.006	.006	.004	.004	.005	.006	.005	.005	.004	.003	.002	.004	.006	.004	.000	.002	.002	.004	.004
26	.003	.004	.002	.002	.002	.003	.002	.002	.004	.003	.004	.003	.001	.001	.001	.003	.004	.004	.006	.005	.004	.004	.003	.004	.003
27	.003	.002	.006	.004	.002	.002	.007	.006	.007	.004	.004	.003	.005	.003	.003	.003	.004	.003	.007	.005	.005	.005	.005	.001	.004
28	.002	.003	.004	.005	.004	.003	.004	.005	.006	.008	.006	.005	.006	.002	.003	.001	.003	.006	.002	.002	.002	.002	.003	.002	.004
29	.002	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.002	.005	.002	.005	.002	.002	.005	.005	.001
AVG.	.003	.004	.004	.003	.003	.004	.004	.004	.005	.005	.005	.004	.004	.004	.004	.004	.003	.004	.004	.004	.004	.004	.004	.003	.004

BERTHOUD PASS, COLORADO - MEAN ANNUAL HOURLY PRECIPITATION BY DAYS
STATION Q-12 PARK, FOR MONTH OF MAR.

	HOURS AM													HOURS PM										DAY
DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG.
1	.004	.001	.001	.001	.001	.002	.002	.002	.002	.003	.003	.002	.002	.007	.008	.003	.004	.003	.003	.005	.002	.002	.002	.002	.003
2	.003	.002	.002	.001	.002	.002	.003	.004	.002	.002	.000	.002	.002	.004	.003	.002	.005	.003	.005	.008	.008	.009	.007	.006	.004
3	.007	.006	.010	.010	.009	.008	.005	.007	.011	.008	.008	.007	.010	.010	.009	.004	.009	.007	.003	.002	.007	.007	.006	.007	.007
4	.002	.003	.002	.002	.003	.002	.003	.006	.004	.004	.004	.009	.003	.001	.002	.001	.002	.001	.000	.001	.002	.004	.003	.002	.003
5	.005	.004	.005	.005	.002	.005	.003	.003	.003	.007	.003	.006	.006	.003	.004	.001	.002	.002	.001	.001	.002	.001	.000	.002	.003
6	.002	.001	.002	.002	.007	.003	.005	.006	.002	.004	.002	.002	.001	.001	.000	.001	.002	.000	.001	.003	.002	.001	.001	.003	.002
7	.001	.002	.004	.005	.003	.002	.003	.004	.004	.006	.005	.004	.001	.002	.004	.001	.003	.004	.004	.002	.001	.002	.000	.001	.003
8	.000	.001	.001	.001	.002	.008	.007	.000	.000	.001	.001	.002	.001	.001	.001	.003	.002	.001	.001	.002	.002	.001	.001	.001	.002
9	.002	.000	.000	.000	.001	.001	.004	.003	.003	.004	.005	.017	.003	.005	.005	.006	.009	.010	.005	.003	.006	.005	.003	.010	.005
10	.005	.002	.004	.003	.004	.004	.003	.003	.003	.004	.005	.003	.004	.003	.003	.001	.000	.000	.002	.002	.002	.006	.005	.001	.003
11	.001	.003	.002	.003	.003	.007	.005	.007	.004	.003	.004	.003	.002	.008	.004	.003	.003	.006	.003	.002	.001	.003	.005	.005	.004
12	.004	.002	.003	.003	.002	.004	.001	.002	.000	.000	.002	.002	.005	.003	.003	.004	.004	.006	.005	.007	.004	.004	.001	.001	.003
13	.001	.001	.002	.002	.001	.001	.001	.002	.003	.002	.003	.005	.005	.003	.006	.007	.016	.005	.006	.007	.003	.003	.003	.005	.004
14	.012	.009	.007	.007	.005	.007	.003	.004	.009	.012	.009	.004	.003	.002	.002	.012	.010	.010	.006	.006	.004	.007	.007	.003	.007
15	.007	.007	.007	.007	.007	.008	.004	.002	.003	.003	.004	.001	.003	.003	.003	.004	.006	.002	.009	.005	.004	.004	.001	.004	.005
16	.002	.003	.004	.005	.003	.005	.003	.003	.002	.001	.001	.001	.002	.003	.005	.005	.006	.002	.001	.000	.003	.004	.004	.009	.003
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18	.004	.003	.008	.012	.007	.003	.003	.002	.003	.003	.003	.001	.002	.007	.007	.003	.003	.004	.002	.004	.006	.008	.007	.008	.005
19	.007	.005	.010	.010	.007	.006	.008	.006	.005	.004	.003	.002	.007	.007	.006	.005	.003	.005	.004	.002	.002	.000	.000	.001	.005
20	.000	.002	.004	.002	.002	.003	.002	.002	.003	.004	.001	.001	.002	.002	.002	.002	.000	.005	.002	.003	.001	.001	.001	.002	.002
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27	.004	.002	.004	.004	.005	.001	.001	.002	.002	.003	.000	.003	.002	.001	.001	.004	.006	.004	.003	.003	.005	.007	.005	.005	.003
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AVG.	.004	.003	.004	.004	.004	.004	.004	.003	.004	.004	.004	.003	.003	.004	.004	.004	.004	.005	.005	.004	.005	.005	.004	.004	.004

BERTHOUD PASS, COLORADO - MEAN ANNUAL HOURLY PRECIPITATION BY DAYS
STATION Q-12 PARK, FOR MONTH OF APR.

	HOURS AM													HOURS PM										DAY
DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG.
1	.002	.002	.002	.001	.001	.002	.002	.006	.006	.004	.001	.002	.007	.007	.013	.013	.004	.001	.007	.006	.004	.002	.004	.003	.004
2	.002	.004	.004	.003	.006	.006	.010	.013	.007	.010	.015	.019	.017	.014	.015	.016	.016	.012	.010	.009	.007	.010	.008	.009	.010
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13	.007	.007	.008	.005	.009	.010	.007	.011	.012	.010	.012	.010	.005	.004	.015	.004	.011	.003	.000	.002	.002	.003	.002	.002	.007
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AVG.	.004	.005	.005	.004	.004	.003	.005	.005	.005	.005	.005	.005	.005	.005	.006	.005	.006	.005	.005	.005	.005	.005	.005	.003	.005

☆U.S. Government Printing Office: 1977-780-949/91 Region 8

Judson, Arthur. 1977. Climatological Data From the Berthoud Pass Area of Colorado. USDA For. Serv. Gen. Tech. Rep. RM-42, 94 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521

Monthly, daily, and hourly meteorological data, collected irregularly from 1926 through 1977, are presented in tabular form. Complete year long data on temperature, precipitation, snow depth, and wind from three mountain sites surrounding Berthoud Pass are analyzed for the period 1963 through 1975.

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Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture
Fort Collins, Colorado 80521

USDA Forest Service
General Technical Report RM-43

Importance, Preservation and Management of Riparian Habitat:

A Symposium

Tucson, Arizona

July 9, 1977



Foreword

The material offered in this symposium is both urgently needed and late in coming. Only in very recent years have scientists and managers begun to shift their perspective on riverine systems away from localized, single-practice values toward a broader, more cooperative and ecological set of approaches.

The dearth of relative and detailed historic data on riparian habitats is lamentable. We begin investigations on a complex and closely interwoven ecosystem without a reliable baseline. Much of our knowledge to date focuses on the aftermath of decades of abuse. But armed with this hindsight, we are beginning to collect, organize and apply hard data to difficult problems. What percentage of breeding birds are dependent on riparian habitat? How much grazing is too much? How many species of plants occur only in riverine ecosystems?

We have begun the long and expensive task of quantifying our generalities about the riparian habitat, so that we can offer valid alternatives to managers in their attempts to preserve the scant remnants of what was once a vast network of thriving and varied habitats.

Agencies and individuals that favored cutting, grazing, damming, and channelizing were opposed by those who favored preserving intact areas that supported unique plant and animal species, or were of high recreational or esthetic value. We are beginning to reevaluate both these polarized positions, realizing that entire riverine systems cannot be solely maintained for a single interest, whether it be water salvage or the remnant population of a species endangered by our activities.

This symposium stresses the continuity and interrelationships of riparian ecosystems, their wildlife and vegetation, historic and current uses. We have designed this proceedings to bring together material that represents the current state of knowledge, and to point out directions for the next critical steps in the interlocking problems of research and management.

This symposium and its proceedings evolved after much planning. Some individuals on the steering committee have discussed a symposium such as this for several years. However, with riparian research and management still in its infancy, only recently has a good symposium seemed possible. Even now many of the prominant researchers and managers whom we contacted during the preparation of the symposium felt that their grasp of the workings of riparian ecosystems was still inadequate. We found research projects and management plans developing as rapidly as the state of the art allows in the western United States, especially the arid Southwest. And although subjects such as river recreation are developing rapidly in the eastern United States (see Proceedings, River recreation management and research symposium--January 24-27, 1977, General Technical Report NC-28, North Central For. Exp. Stn., Minneapolis, Minn.) one is hard pressed to find riparian projects east of the Rocky Mountains, except for those associated with the continuing destruction of even more riverine ecosystems.

We predict that by the early 1980's research projects currently being planned and undertaken will lead to a vast expansion in the knowledge necessary to properly manage riparian ecosystems. In 3 to 5 years, a full-scale workshop on sophisticated means of research, preservation, and management of riparian habitat seems possible. Today we offer a relatively primitive state of the art in the "importance, preservation, and management of riparian habitat." If our predictions are correct, this science will have developed from a newly born discipline into progressing maturity within two decades. Farsighted men like the late Douglas C. Morrison, to whose memory this symposium is dedicated, will have played a major role in the birth of scientific management of riparian habitat.

R. Roy Johnson

USDA Forest Service
General Technical Report RM-43

Importance, Preservation and Management of Riparian Habitat:

A Symposium

Tucson, Arizona
July 9, 1977

Technical Coordinators:

R. Roy Johnson
National Park Service
and
Dale A. Jones
USDA Forest Service

Cosponsored by:
Arizona Game and Fish Department
Arizona-New Mexico Section, The Wildlife Society
Arizona State University
Bureau of Land Management
Museum of Northern Arizona
National Park Service
U.S. Fish and Wildlife Service
USDA Forest Service

Acknowledgment

We wish to thank the authors of the papers in this proceedings for their enthusiasm and cooperation. The one day available for the symposium provided insufficient time to present all of the fine papers brought to our attention. Thus, we are pleased to have several excellent contributed papers published in the same volume with the presented papers. The authors of contributed as well as presented papers submitted camera-ready manuscripts to expedite their publication. The Bureau of Land Management provided generous financial support for the publication of these papers.

Finally, we acknowledge those who assisted with the mechanics of organizing and conducting a symposium of this scope. The steering committee, composed of representatives from the sponsoring agencies listed, assisted in organizing and publicizing the symposium. And the fact that you are able to read these papers so shortly after the symposium is due largely to the combined efforts of the authors and the Publications Group, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. To all of these we owe our sincere thanks.

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Abstract

Twelve presented and 15 contributed papers highlight what is known about this unique, diminishing vegetative type: characteristics, classification systems, associated fauna, use conflicts, management alternatives, and research needs. Speakers stressed the continuity and interrelationships of riparian ecosystems, their wildlife and vegetation, historic and current uses.

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Session I

Discussion Leader: Dale Jones
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Importance, Preservation, and Management of Riparian Habitats: An Overview[1]

Steven W. Carothers [2]

In the early 19th century, huge and numerous squawfish were being taken along the lower Gila; there was a commercial fishery of the humpback sucker in the San Pedro; wild turkeys hatched out of the waist-high grasses of the Auga Fria; and grizzly bears and mountain lions were encountered with alarming frequency in the riparian woodlands associated with some of these drainages. The historical literature that documents the early exploration and settlement of the southwestern United States is replete with similar accounts of the original condition of the area's rivers, streams and springs (see Lacey et al., 1975; Hastings and Turner, 1965, for original references).

The river valleys of the arid Southwest have undergone significant physical and biological changes since the early 1800's. This change has involved almost exclusively a deterioration of the natural resources. Drainages like the Gila and San Pedro Rivers that once supported pristine riparian communities are now, in many sections, dry and devoid of native trees and shrubs. Concomitant with the deterioration of the riparian habitats, the range habitats throughout the same area also reflect a decline in the production of palatable forage plants and an increase in topsoil erosion.

We can, and have, argued about the causes of deteriorating range quality. But there is, in my opinion, no controversy concerning the causes of the irrevocable consumption of the riparian habitat that has occurred in less than 150 years. The imminent demise of the riparian woodland can be most assuredly linked to the land utilization practices of man.

The title of this symposium indicates that we will address the "importance, preservation and management" of riparian habitats. The word "importance" here is meant to reflect the relative contribution of riparian habitats in a natural ecosystem; "preservation and management" refer to implementing land management practices that will forestall the possible extinction of these habitats. We are tempted to approach these issues in purely scientific definitions. But the issues extend beyond the realm of biology. Man has contributed, in large part, to these problems. It is only by examining how he views the riparian habitat as important to his economic base, and thereby consumes this resource, that we can understand why it is in danger of extirpation.

The settlement patterns of the native American Indians clearly reflect the initial consumptive use of riparian habitats. They first settled the river valleys, needing water for themselves, and subsequently drinking water for livestock and irrigation water for crops. This pattern of consumption accelerated greatly in the early 1820's, with the settlement of the early Anglo-Americans in the Southwestern river valleys. Prospectors, farmers, and ranchers all found uses for the limited water and its associated vegetation. The area was rapidly settled and in 1896 the Governor of Arizona Territory could report, "In Arizona by 1883-84 every running stream and spring was settled upon, ranch houses built, and adjacent ranges stocked." (Report of Governor, 1896:21 fide Hastings and Turner, 1965).

The settlers cleared large expanses of native vegetation, using some for building materials; but for the most part, they did not view the woodlands as a valuable resource, and removed them so that the soil of the alluvial bottom could be put into "production" for agricultural and domestic livestock grazing purposes. Eventually, farming and ranching became thriving concerns; river water was channeled into irrigation canals, wells were excavated and in time the water tables began to drop. Responding to changing water regimes, damaging floods, or in simple attempts to increase the yield of the land, dams were finally constructed, inundating and destroying even more riparian woodland and free-flowing streams and rivers. By the late 1920's, America had shifted from a rural to a predominantly urban population. The beginning of an urban-industrial civilization in the arid Southwest required the

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[1]Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9 , 1977.

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utilization of many innovative technological advances in developing veritable oases where once only parched deserts prevailed. As population centers experienced rapid and prolific expansion, terms such as water production, water management, and water salvage became very meaningful.

As recently as the late 1960's, belts of native riparian woodland along the river valleys of central and southern Arizona were still being actively removed by water salvage and flood control agencies. These "phreatophyte control" and channelization projects were easily justified when based on the standard cost/benefit ratio that was used for project evaluation at the time. The important parameters of these evaluations were: 1) streamside vegetation requires substantial amounts of water, water that is lost to the atmosphere through evapotranspiration; and 2) streamside vegetation impedes the rapid transport of flood waters and increases the apparent severity of floods by temporarily and partially damming channels, thus forcing high water into the adjacent floodplain lands.

The question of how much water is gained and to what degree floods are prevented by phreatophyte control and channelization has been a battle of the minds almost since vegetation removal was first suggested (see Lacey et al., 1975; Paylor, 1974, for references). Still, we have not seen the last of phreatophyte control and streambed channelization in the Southwest, and we know for certain that additional dams will consume even more of the still extant riparian areas. But the most insiduous threat to the riparian habitat type today is domestic livestock grazing. Many riparian areas appear to be in good health; on closer examination, we find that while the mature vegetation approaches senescence, grazing pressures have prevented the establishment of seedlings. We are very concerned that when many of these mature stands of trees die of natural causes, there will be no young forms to take their place. Heavy grazing pressures can and do produce even-aged, non-reproducing vegetative communities. Our concern for this habitat's survival can only mount until this situation is remedied.

For more than a century, then, the riparian habitats of the Southwest were viewed only in terms of their consumptive value, while their values for non-consumptive purposes--aesthetics, recreation, wildlife, and so on--were largely ignored. It was not until the mid-1960's that various agencies and individuals, particularly in the Arizona Game and Fish Department (see Bristow, 1969; Gallizioli, 1965) and the United States Forest Service (pers. communication, Dale Jones and Douglas C. Morrison) began to point out that substantial numbers of both game and non-game wildlife species were dependent upon riparian vegetation. And it was only in the fall of 1968 that efforts to quantify the impact of streamside vegetation removal on wildlife were first undertaken. It is for his efforts in this regard that this symposium is dedicated to the late Douglas C. Morrison.

Working through the wildlife staff on the Coconino National Forest, in 1968 Mr. Morrison participated in the design of a research project that would quantify the effects of phreatophyte control on breeding birds in the native riparian woodland of the Verde River. A Forest Service contract was awarded to the Department of Biology at the Museum of Northern Arizona in the spring of 1969. Through Mr. Morrison's efforts, the study was funded for two years by the Forest Service. After that time, the Arizona Game and Fish Department supported the project for an additonal three years.

The results of that study (see Carothers et al., 1974) substantiated, for the first time, two facts that had long been suspected by many wildlife biologists: 1) that vegetation manipulation in native riparian communites was extremely detrimental to breeding bird populations, the extent of the impact being significantly correlated with the degree to which phreatophytes were removed, and 2) that for a given number of acres of habitat, the riparian type supports higher population densities than any other forest habitat type. Indeed, the surprising discovery resulting from these studies is that the homogeneous cottonwood riparian type of the Verde River contains some of the highest avian population densities per unit area that have been recorded in the continental United States. Recently, other investigators working in the river valleys of the Gila (Hubbard, 1971), the Colorado (Anderson, Ohmart et al., this symposium; Carothers and Sharber, 1976) and the Salt (Johnson and Simpson, 1971) have demonstrated the remarkabley high wildlife potential of riparian habitat types.

The influence of the riparian type on wildlife is not limited to those animal species that are restricted in distribution to the streamside vegetation. Preliminary investigations conducted by us (see Stevens et al., this symposium), in both river valley and mountain riparian types, demonstrate that the population densities of birds in habitats adjacent to the riparian type are influenced by the presence of a riparian area. Our present interpretation of these preliminary data is that when a riparian habitat is removed or severely manipulated, not only are the riparian species of the area adversely influenced, but wildlife productivity in the adjacent habitat is also depressed. The actual width the zone of influence riparian habitats have on adjacent habitat wildlife productivity may, for some animal species, extend several hundred meters beyond the edge of the stream-

side vegetation. Under the auspices of the Forest Service, we are presently attempting to determine this for a variety of riparian types in Arizona and New Mexico.

Thus, the history of man's use of the riparian habitats in the Southwest indicate that it has been and continues to be an important and valuable asset to the settlement and progress of this country. On the other hand, ecological research on this habitat type has conclusively demonstrated that riparian areas are integral and indispensable components of desert and mountain ecosystems. Past riparian habitat management practices have resulted in widespread destruction of these areas. That they are non-renewable resources as suggested by Lacey et al. (1975) is a frightening possibility. And even though there are many Southwestern drainages still forested by riparian vegetation, current land use practices still threaten the future existence of these native communities.

We should not look back on the land management practices of the past with too much remorse and certainly with no blame. A summary of man's activities in and the destruction of woodlands, streams, and rivers simply reflects man's successful settlement of this arid land, allowing those of us who live and work in the Southwest the lifestyle we now enjoy. Land management practices of the past should, in fact, be a foundation for learning and understanding how to cautiously move forward in our interactions with the environment.

We are here today to exchange information. The time is at hand for the ecologist, economist, engineer, environmentalist and land manager to strike a compromise...a compromise that will provide a future for native Southwestern riparian habitat types. Accepting and assessing the environmental mistakes of the past, becoming aware of the intricate needs and associations of man and the environment can lead to the implementation of land management practices that will achieve this end.

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Classification of Riparian Habitat in the Southwest[1]

Charles P. Pase, and Earle F. Layser[2]

Abstract.--The riparian areas in Arizona and New Mexico are uniquely productive wildlife habitats. A tentative classification based on the work of Brown and Lowe is proposed as a working model. Six biomes, nine series and 23 associations are tentatively recognized. Additional research is proposed to further refine the classification. The classification of riparian vegetation can provide a strong management tool.

INTRODUCTION

Riparian habitats in arid and semiarid environments are unique reservoirs of plant and animal diversity. Breeding bird densities are likely to be high, especially in the most productive Fremont cottonwood (Populus fremontii) stands, with as many as 1,000 pairs or more per 100 acres (Carothers and Johnson 1975). Also, the small but highly productive riparian communities support the greatest variety of birds (and probably other vertebrates) in the Southwest.

"Riparian" type habitats are streamside or riverside communities, stretching from high forest to low desert. Soil moisture is seldom a limiting factor, at least for successfully established perennials, although surface water may be lacking at times in marginal areas. The wide array of habitats thus included sustains an equally wide array of plant and animal communities.

FLORISTIC HISTORY

The southwestern mountains and valleys contain diverse floristic elements, which have mixed and adapted to provide a unique flora.

Madro-tertiary elements such as Celtis, Juglans, Prosopis, Platanus, and Sapindus along the Mexican cordillera are representative of families with strong subtropical affinities. During the drier postpluvial period, increasing dryness forced their retreat to the riparian zones, where today they form characteristic deciduous forests and woodlands. According to Martin (1963), many of the Mexican flora and fauna probably were isolated in the southern Arizona mountains during the mid-postglacial, perhaps 4,000 to 8,000 years ago. If so, modern communities were relatively recently composed.

During the Pliocene-Pleistocene era, Arcto-tertiary Geoflora extended southward into the mountains of Arizona and New Mexico, establishing such northern-affinity genera as Alnus, Salix, Populus, and Betula. The same xerothermal conditions--the so-called altithermal--that isolated the mexican plateau elements also trapped these genera in moist, riparian habitats (Lowe 1964).

Development of modern riparian plant and animal communities, and the isolation of many species into highly restricted habitats, happened relatively recently. Further restriction of these small, sensitive areas by agriculture, recreational, and other developments may pose a serious threat to species largely or wholly dependent on this habitat.

THE RIPARIAN ZONES

Despite the species diversity and productivity of the riparian zone, it is relatively small. The total riparian area in Arizona is some 279,600 acres (Babcock 1968), of which 100,700 acres are along the Gila River. The areas within New Mexico may be comparable or slightly larger, with the inclusion of substantial areas of mesquite, Fremont cottonwood, and salt cedar (Tamarix spp.) along the main stem of the Rio Grande.

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[1]Paper presented at the Importance, Preservation and Management of the Riparian Habitat Symposium, held at Tucson, Arizona, July 9, 1977.

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The most productive Fremont cottonwood areas are surprisingly small--about 6,000 to 8,000 acres in Arizona, according to Barger and Ffolliott (1971). Unfortunately, estimates of area by plant associations are not yet available for other types. However, National Forests in USDA Forest Service Region 3 plan to inventory riparian habitat, because of its high wildlife value, as part of forest land management planning.

Riparian communities generally exhibit a predictable vertical zonation in relation to each other (fig. 1), although absolute upper and lower limits may vary within the Region (Freeman and Dick-Peddie 1970). Certain species, such as box elder (Acer negundo), are found throughout the area, and may occur as scattered minor components in a number of related associations. Others such as Salix irrorata, have much lower ecological amplitudes.

WHY A CLASSIFICATION SYSTEM?

While there is substantial intergradation between adjacent riparian units, certain species or combinations of species tend to dominate stands. Recognition of these natural ecological units may help the land manager as follows:

1. It would assist the identification, description, and communication about riparian habitats.
2. Utilizing a classification system would allow for more uniform identification of the different riparian situations, thus providing a means to more accurately assess the distribution and the relative amounts of the different communities that may exist.
3. Development of the classification would provide an inventory of the major plant that exist in the different communities Inventory of fauna associated with the different plant communities could also be done.
4. Successional roles of the different species would be better determined which would allow more accurate prediction of results of management practices.
5. It would provide a framework for additional research and reporting of research results.

The development of a site-based vegetation classification system for riparian habitats is not an end in itself. The purpose of the classificatio is to provide land and resource managers with a management tool. As pointed out above, this would enable managers and research to better deal with problems involved in the management of riparian habitats in the Southwest.

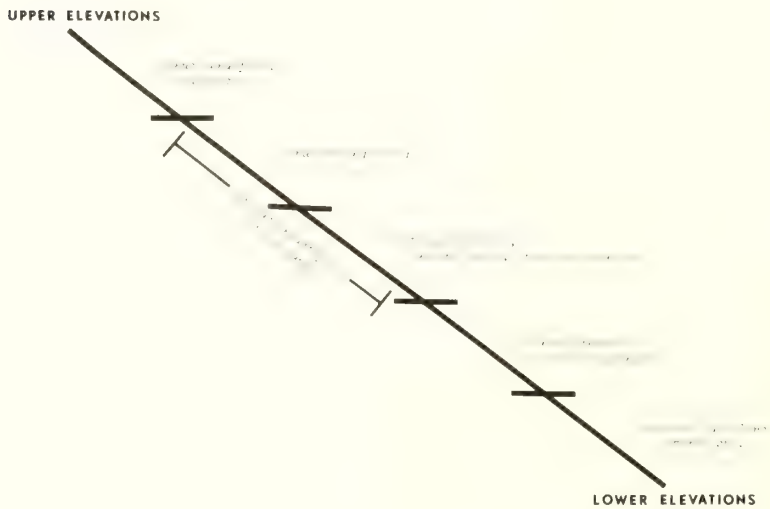


Figure 1.--Altitudinal zonation of major riparian communities in the Southwest.

STATUS OF CLASSIFICATION

While there have been notable studies of riparian vegetation in the Southwest (Campbell and Green 1968; Lacey, et al. 1975; Lowe 1961; Freeman and Dick - Peddie 1970; Horton 1960), there has been only little work to date towards development of a systematic classification of riparian vegetation or sites. Such classification involves methodology as described by Pfister and Arno (1977). In generalized terms this means:

1. Sampling of stands or communities in respect to ecological and floristic characteristics.

2. Analyzing the above data by various techniques.

3. Considering various groupings (classes) based on the data and analysis; and selecting groupings appropriate to the purpose.

4. Defining the classes as simply and precisely as possible.

The taxonomic classification is then used to apply the appropriate class name to communities as they are encountered in the field. This is called "identification", and differs from the actual development of the classification (Bailey, et al. in press).

A TENTATIVE CLASSIFICATION OF RIPARIAN COMMUNITIES
(generally after the system of Brown and Lowe 1974)

Boreal Riparian Mixed Forest Biome
- Spruce--Mixed Shrub Series
  - *Picea pungens* - *Alnus tenufolia* Association

Temperate Riparian Deciduous Forest Biome
- Mixed Broadleaf Series
  - Mixed Broadleaf Associations (fig. 2)
  - *Acer negundo* Associations
  - *Alnus oblongifolia* Associations (fig.3)
  - *Platanus wrightii* Associations (fig. 4)
  - *Fraxinus velutina* Associations (fig. 5)
  - *Juglans major* Associations
- Cottonwood--Willow Series
  - *Populus fremontii*--Mixed Broadleaf Associations
  - *Populus fremontii* Associations (fig. 6)
  - *Salix bonplandiana* Associations
  - *Populus fremontii*--*Salix gooddingii* Associations
  - *Salix gooddingii* Associations
  - *Populus angustifolia* Associations

Subtropical Riparian Evergreen Forest Biome
- Palm Series
  - *Washingtonia filifera* Associations

Boreal Riparian Woodland Biome
- Willow Series
  - *Salix bebbiana* Associations
  - *Salix irrorata* Associations
  - *Salix* mixed Associations (fig. 7)
- Alder Series
  - *Alnus tenuifolia* Associations
  - *Alnus tenuifolia*--*Salix* Associations (fig. 8)

Temperate Riparian Deciduous Woodland Biome
- Willow Series
  - *Salix exigua* Associations

Subtropical Riparian Deciduous Woodland Biome
- Mesquite Bosque Series
  - *Prosopis juliflora* Associations
  - *Prosopis juliflora*--Mixed narrowleaf (*Tamarix*, *Chilopsis*, *Celtis*) Associations
- *Tamarix* Disclimax Series
  - *Tamarix chinensis* Associations

The above list is not to be considered complete. Lacey et al. (1975) suggests that a number of these should be subdivided further. The listing, however, generally displays the current "classification" of riparian vegetation, and represents a tentative identification of types which are a first approximation toward the development of a classification.



Figure 2.--Mixed broadleaf Association with *Platanus*, *Populus*, *Fraxinus*, *Juglans*, *Prunus*, and *Sapindus*. This is primary habitat for rose-throated becard and Apache fox squirrel. Arroyo Cajon Bonito, Sonora, Mexico.



Figure 3.--Alnus oblongifolia Association on the upper Gila River. This type occur only on upper middle elevation living streams, where roots can reach the water table during much of the year (Freeman and Dick-Peddie 1970).



Figure 5.--A nearly pure stand of Fraxinus velutina along Ash Creek, Rincon Mountains. Heavy past cattle use will be restricted under new management plans in this area.



Figure 4.--Platanus wrightii Association along Turkey Creek, Rincon Mountains, Coronado National Forest. Limited understory and absence of reprodection charaterizes these grazed channel bottoms.



Figure 6.--Narrow bands of Fremont cottonwood, sycamore, velvet ash and Goodding willow provide sharp contrast to dry grassland communities on the Prescott National Forest.



Figure 7.--Salix Mixed Association, upper Black River, Apache-Sitgreaves National Forest. S. pseudocordata and S. lasiolepis provide shade and cover along one of Arizona's productive trout streams. The area is valuable elk summer range, with little livestock use.



Figure 8.--A lush Alnus tenuifolia - Salix Association flanks Los Pinos Creek on the Carson National Forest. The narrow, overhanging riparian woodland community greatly improves trout habitat.

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Inventory of Riparian Habitats[1]

David E. Brown[2]
Neil B. Carmony[3]
Raymond M. Turner[4]

Abstract.--A recently published map of Arizona's perennial streams and important wetlands was presented and discussed. Perennial streams are illustrated rather than riparian vegetation because the streams are of more direct biotic significance and are more readily identifiable. Inventory procedures used in preparing the map were outlined and the categories of streams and wetlands described. A planned revision of this map will incorporate selected altitude contours, base-flow classes, and an inventory of seasonal streams.

The map distributed to members of the symposium presents Arizona's perennial streams and important wetlands; it is a synthesis of information compiled by numerous investigators (Brown, Carmony, and Turner, 1977). While the map implies the distribution of riparian and marshland vegetation, it does not show riparian vegetation directly: rather, it shows the distribution of live streams and wetlands—the physical basis upon which riparian and wetland biotic communities depend.

Efforts and plans to modify and even eliminate many of the Southwest's remaining riparian communities have stimulated interest in the inventory and preservation of riparian habitats. One of the results of this interest was the formation in 1972 of a "Riparian Recovery Committee" within the New Mexico-Arizona Section of the Wildlife Society. This committee has promoted the investigation of riparian habitats, and its efforts resulted in this symposium sponsored by the U.S. Forest Service. It soon became apparent to the committee and to other workers involved with riparian vegetation and fauna that the classification and inventory of the various riparian habitats is a necessary first step in understanding the problems associated with riparian habitats.

Because of the immense biological importance of these habitats, it was originally planned to prepare a map of Arizona's natural and potential riparian deciduous forests and woodlands as described by Lowe (1964, p. 60-62) and as classified by Brown and Lowe (1974a, 1974b). An informal program of collaboration between the Arizona Game and Fish Department and the U.S. Geological Survey was initiated to map riparian vegetation from low-level aerial photographs of sub-Mogollon Arizona (photographs were taken in June 1973, and later checked at a limited number of sites for ground truth). Although the determination of established deciduous forests proved feasible, it soon became apparent that the inventory of riparian forest vegetation in itself left much to be desired for the purposes of biotic assessment. Two major deficiencies of this approach were:

1. Extreme variations in the biota within the riparian deciduous forests were not measured. Deciduous forests can and do exist along near-perennial as well as perennial streams. Habitats along intermittent or nearly perennial streams do not, of course, support fish and other important aquatic forms that are found in perennial streams. Therefore, the presence or absence of a potential riparian aquatic biota and its predators, e.g.

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black hawks *(Buteogallus anthracinus)*, ospreys *(Pandion haliaetus)*, bald eagles *(Haliaeetus leucocephalus)*, otters *(Lutra canadensis)*, and kingfishers *(Megaceryle alcyon, Chloroceryle americana)*, would not be indicated by an inventory of riparian deciduous forests alone.

2. The dynamic nature of riparian communities is such that potential riparian deciduous forests could not always be determined. It soon became apparent that floods, intensity of livestock grazing, geologic and hydrologic conditions, and other factors could continually or temporarily affect the presence of several deciduous-forest species and thereby determine the presence of the forest community itself. These factors can result in the presence of successional stages from seedlings to decadent stands, or in the absence of trees altogether. These conditions may prevail over a relatively short term or may be as long as several human generations.

For these reasons we decided to determine he feasibility of modifying existing map(s) of ive (perennial) streams and rivers to show wet- ands and potential riparian vegetation. To our urprise no comprehensive inventory of perennial- low reaches existed, and the only map of "perma- ent streams" available for Arizona was a small- cale drainage map by Miller (1954).[5] This map as presumably based on fish collections and, hile serviceable, was very much in need of evision. Perennial-stream data were trans- erred and extrapolated from Miller's map to a :500,000-scale U.S. Geological Survey map of rizona. This became the base work map. U.S. eological Survey minimum flow records were used, here available, to identify the nature of flow n streams. Those streams for which no stream- low records were available became the subject or interviews with wildlife managers, U.S. Forest ervice personnel, back packers, fishermen, and thers who had visited them. Fortunately, these fforts coincided with a statewide stream inventory onducted by the Arizona Game and Fish Department Silvey, 1977) and with a statewide map inventory f biotic resources, including perennial streams, y regional personnel of the Arizona Game and Fish epartment. Personal knowledge and investigation y the authors supplemented these data and allow- d for further comparison and correction. A ajor but not sole criterion used in determining the permanence of flow in an ungaged stream was the presence or absence of fish. We considered as perennial those streams which supported a fish fauna regardless of minimum flow. Perennial streams, as classified here, may have surface water only in pools during times of extreme drought or other low-flow periods.

It soon became obvious that there are three major categories of perennial streams based on the biota actually or potentially present. These categories and their characteristics are:

1. Unregulated perennial streams. These streams usually possess a native and/or introduced aquatic fauna. Those that are now devoid of native fishes possess the potential for restoration if the native species formerly present are still available. Native riparian communities and their associated biota are actually or potentially present, and the riparian exotic saltcedar (*Tamarix chinensis*) can be expected to be poorly represented. Some of these streams may be partially regulated by relatively small upstream storage or diversion.

2. Regulated perennial rivers and streams. These rivers and streams are characterized by a totally unnatural streamflow pattern. They lack normal seasonal high water, and on occasion base flows may be artificially reduced or eliminated. There may also be major daily changes in streamflow that negatively affect the life cycles of many fish species. Water-temperature regimes are also greatly altered. This factor, and the lack of normally occurring high flows, tend to inhibit natural reproduction of those plants and animals which evolved with a natural flowing system. These "managed" streams are now often largely populated by introduced fishes, reptiles (for example, the soft-shelled turtle *(Trionyx spinifera)*), and amphibians (for example, the bullfrog *(Rana catesbeiana)*), and the native biota are reduced and some species are extirpated. Exotic plants occupy many extensive riparian habitats. Numerous species of birds characteristic of riparian communities usually persist, however.

3. Stream reaches containing only effluent or waste-water dischcarge. These stream reaches are characterized by an almost completely introduced aquatic fauna adaptable to polluted waters, and include mosquito fish *(Gambusia affinis)*, sailfin

[5] Perennial-flow reaches are indicated on U.S. Geological Survey topographic and other maps, but in many cases these streams do not appear to have been adequately field checked and are in error.

mollies *(Poecilia latipinna)*, carp *(Cyprinus carpio)*, and crayfish *(Astacidae)*. The riparian vegetation is usually a mixture of native and exotic species. The status of these reaches is expected to change significantly in the future as consumptive uses for these waters are developed.

Important wetlands, the other major category shown, are separated into two size categories, classified by regulatory criteria similar to those for perennial streams, and plotted on the base map in the appropriate size and color. Wetlands are here defined as poorly drained lands, seasonally or periodically submerged lands, and shallow bodies of water supporting emergent vegetation. Important wetlands are those that, because of their size and/or location, are much used by nesting, migrating, and wintering waterfowl or that provide habitats for rare, unusual or interesting wetlands species of flora and fauna. We were highly dependent on Game and Fish personnel, especially Richard L. Todd and Thomas K. Britt, for the locations of many of these major wetlands.

All these data were transferred from the 1:500,000 work map to a U.S. Geological Survey Drainage Map, scale 1:1,000,000. This map is now out of print but approximately 1,800 copies are in circulation. Its rapid dissemination was due to the interest of fishermen, hikers, realtors, gold miners, and others as well as those interested in natural-resource inventory. Because of this broad appeal we intend to publish a second edition, possibly in 1978. In an effort to make the map more useful and meaningful to biologists, we propose to incorporate additional data and criteria, in addition to making those corrections called to our attention. These new items include:

A. The addition of altitude contours 1,000 ft, 3,500 ft, 5,500 ft, and 7,750 ft above mean sea level. These contours, based on the occurrence of riparian species, were selected after consultation with biologists possessing knowledge of Arizona's endemic fishes (R. R. Miller; W. L. Minckley; W. Silvey, personal communications, 1977). These contours will roughly partition the state into arctic-boreal, cool-temperate, warm-temperate, and subtropical zones. In addition to providing information as to which species of riparian flora and fauna can be expected, these contours will allow for rapid identification of cold montane waters and associated fishes, waters dominated by cool-water fish, waters dominated by warm-water fish, and waters populated exclusively by warm-water species.

B. The division of unregulated streams into size categories on the basis of base-flow data. Streams would be categorized as those possessing a 7-day minimum flow of >50 cubic feet per second (ft^3/s), >10-<50 ft^3/s, and <10 ft^3/s. These divisions would roughly separate Arizona's natural flowing streams as follows:

1. Base flow >50 ft^3/s

Unregulated perennial streams with a base flow greater than 50 ft^3/s potentially support a varied aquatic fauna of both native and introduced species. Some fish species present can be expected to reach sizes of 20 lbs or more. Consequently, these rivers are potential habitat for some of the larger piscivorous animals, e.g. otter, black bear *(Ursus americanus)*, bald eagle, osprey, etc. While these rivers potentially support all native species of riparian vegetation common to their life zone, periodic floods and seasonal fluctuations in flow regimes usually prevent the establishment of "gallery" forests, and long stretches of river are often characterized by wide, barren flood plains. Examples are few and include the Lower Little Colorado River below Blue Springs, the Verde River from below Perkinsville to Clarkdale, the Verde River from West Clear Creek to Horseshoe Reservoir, and the Salt River above Roosevelt Lake. Formation of a perennial river from effluent discharge is a recent phenomenon in Arizona. Rivers in this class are formed by sewage releases from growing cities and from irrigation return flow. The aquatic fauna is almost entirely introduced, as is the dominant riparian plant, saltcedar *(Tamarix chinensis)*. Native vegetation is profuse, however, and appears to be increasing.

2. Base flow >10-<50 ft^3/s

Unregulated perennial streams in this category can also be expected to support a varied native and introduced aquatic fauna. Select habitats can be expected to support species of fish over 1 lb. These streams are potential habitat for most piscivorous species and normally possess well-developed native riparian communities and their animal associates. Riparian deciduous forests are common features below 6,500 ft. Examples of streams in Arizona with base flows in this range are the Virgin River, Bright Angel Creek, the Verde River above Perkinsville, Oak Creek, the lower portions of West Clear Creek, Black River, north fork of the White River, and the San Francisco River.

3. Base flow <10 ft^3/s

Unregulated perennial streams of this size usually support only the smaller fishes and their predators. The native fish fauna may be rich in species, and a surprising number of amphibians and aquatic reptiles can be expected. Riparian deciduous species frequently form "gallery" forests, and excellent examples are present at many places.

C. We plan also to add seasonal streams. These streams, termed semi-perennial by Zimmerman (1969), flow during the winter and early spring; they do not have a sufficient base-flow component to maintain a surface flow during warm dry months when evapotranspiration losses are high, but can be expected to flow from mid-winter to about April. These streams potentially support well-developed riparian vegetation, including deciduous forests. The aquatic biota is, of necessity, limited to those forms adapted to withstand periods of desiccation, and fishes are lacking. Nonetheless, avian and amphibian species characteristic of, and associated with, riparian forests may be well represented, with the exception of piscivorous species. Such non-piscivorous animals include in the appropriate environments the zone-tailed hawk *(Buteo albonotatus)*, grey hawk *(Buteo nitidus)*, summer tanager *(Piranga rubra)*, blue grosbeak *(Guiraca caerulea)*, Woodhouse's toad *(Bufo woodhousei)*, the canyon tree frog *(Hyla arenicolor)*, etc. These streams will be differentiated from those of an ephemeral nature.

We believe that these inventory procedures are applicable to other Southwestern States and will prove useful in the delineation of their aquatic, riparian, and wetland biotic resources. We suggest that future mapping be at the scale of 1:1,000,000, which would be an effective standard for the illustration of biotic resources because of its easy metric conversions (1 mm = 1 km), adaptability for demonstration purposes, and utility for field use.

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Importance of Riparian Ecosystems: Biotic Considerations[1]

John P. Hubbard[2]

By biotic considerations I am referring to flora and fauna, and specifically I would like to probe the question of the importance that riparian ecosystems play in sustaining the rich biotas of the Southwest, i.e. Arizona and New Mexico. To begin, these two states are among the richest of any in the United States as far as their diversity is concerned in species of plants, terrestrial vertebrates, and many invertebrates. This biotic richness stems from several factors, including the great environmental variety of the region and the fact that several major biotic areas impinge on the area, i.e. the Great Basin, Rocky Mountains, Great Plains, Mexican Plateau, and the Southern (Chihuahuan and Sonoran) Deserts.

New Mexico is the fourth and Arizona the fifth largest of the United States, with areas of 121,666 and 113,909 square miles, respectively. In size these states are thus on a par with such well-known entities as the British Isles, Italy, and the Philippines. In elevation New Mexico ranges from 2800 to 13,161 feet above sea level, while Arizona ranges from near sea level to 12,670 feet. Although often through of as "deserts", both states support extensive montane forests, and New Mexico especially is crowned with alpine tundra in the north. On the other hand, aridity is a dominant climatic feature of the region, and particularly at elevations below 6000 feet surface water is scarce and naturally restricted to a few thousand miles of generally narrow drainageways in the two states.

Floristic diversity is revealed by the fact that New Mexico supports 3500 to 3600 species of higher native plants within its borders (Wagner, 1977), while the latest summary for Arizona lists 3438 (Kearney and Peebles, 1960). For the continental United States and Canada as a whole, an estimated 40,000 to 50,000 species of higher plants have been recorded. Thus, the floras of New Mexico and Arizona comprise about 7 to 9 percent of the total flora of what might be termed temperate North America.

Among terrestrial vertebrates one finds that even higher percentages of the overall temperate North American faunas are recorded in these two states (Table 1).

Table 1. Vertebrate Fauna of the Southwest, Including Species Totals and as Percentages of the Total Fauna of North America North of Mexico.[3]

	Arizona	New Mexico
Mammals		
species	134	139
percent	41.6	43.2
Birds		
species (all)	431	413
percent	62.0	59.4
species (breeding)	245	245
percent	38.0	38.0
Reptiles		
species	93	80
percent	35.2	30.3
Amphibians		
species	21	22
percent	13.5	14.2

As one can see, except for amphibians, Arizona and New Mexico harbor disproportionate portions of the terrestrial vertebrates of temperate North America, with figures ranging from about one-third to almost two-thirds among mammals, birds, and reptiles. Amphibians, which mainly depend on water for reproduction, in the two states constitute about one-sixth of the North American fauna.

[1]Paper presented in Importance, Preservation, and Management of the Riparian Habitat, Tucson, Az, July 9, 1977.

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[3]Data sources include Findley et al., 1975; Hubbard, 1970; Lowe, 1964; Phillips et al., 1964; Stebbins, 1966.

Fishes, although they face an overall carcity of habitats in the Southwest, are onetheless well-represented in the faunas. rizona has 32 native species (Minckley, 973), while New Mexico has 59 species record-d within its boundaries (Koster, 1957). The atter area supports a richer fauna by virtue f its location in both the Atlantic and acific drainages of the continent. In fact, everal species from the very rich ississippian ichthyofauna reach western lim-ts in New Mexico, including the blue sucker Cycleptus elongatus). Even with their lim-ted faunas, these two states still host--or osted--reasonably rich percentages of the verall U.S. fish fauna in their boundaries, .e. 5.3% in Arizona and 9.3% in New Mexico.

From the above it should be apparent hat Arizona and New Mexico are truly diverse n their floras and faunas, even when one argely restricts the discussion of animals o vertebrates. Thousands of species of in-ertebrates also occur in the two states, ncluding especially terrestrial arthropods. or example, Howe (1975) lists almost 700 pecies of butterflies from temperate North merica, and of these about one-third are re-orded from New Mexico and somewhat higher igure from Arizona.

In evaluating the biotic importance of a egion, one approach is through the considera-ion of endemism, i.e. the degree to which pecies are restricted to an area in question. oth Arizona and New Mexico are host to enden-c plants and animals, including vertebrates s well as invertebrates. Although I know f no compendium of such species, several xamples illustrate some of the endemism. or example, among vertebrates New Mexico osts the only known populations of such spe-ies as the White Sands pupfish (Cyprinodon ularosa), Jemez Mountain salamander (Plethodon neomexicanus), and Sacramento ountain salamander (Aneides hardii). Both tates boast endemic plants as well, while ogether they share a number of other endemics hat occur nowhere outside the Southwest, in-luding the minnow genera, Tiaroga and Meda, in the Gila Basin.

Although endemism is an important means f evaluating the biotic importance of an rea, other considerations also pertain. For xample, the kinds of assemblages of plants nd animals are important, and in these two tates virtually unique associations have risen because of the interdigitation and/or ingling of diverse biotas. Such associations re interesting and important form evolution-ry, ecological, and other biological points f view. Unique or unusual assemblages of plants and animals provide scientists and others the extended opportunity to understand better our ecosystems and life itself. An example of a notable biological assemblage is the breeding avifauna of the lower Gila Valley of New Mexico, where species characteristic of the Sonoran, Mexican Plateau, and Holarctic avifaunas occur side-by-side (Hubbard, 1971). That fauna has been compared to another in the ecologically similar San Juan Valley, 250 miles to the north and in the same drain-age basin (i.e. Colorado River). Both avi-faunas have similar numbers of species (i.e. 105 versus 112 in the Gila), but they differ importantly; for example, only 58.7% of the Gila species breed in the San Juan, while only 64.8% of the species in the latter area breed in the Gila (Schmitt, 1976).

The essence of the above comparisons is that not only are Arizona and New Mexico biotically diverse and host to certain endem-ics, but they also show significant and im-portant area-to-area differences in the com-position of biotas occupying similar situa-tions. Each river valley, mountain range, hot spring, or alkaline playa is apt to differ from those occurring nearby, and this fact alone underscores even more the biotic importance of these two states. This is not to imply that other regions are lacking in biotic importance, for such is not the case. However, Arizona and New Mexico stand apart from most other states in having both very rich floras and faunas and in having many factors that promote ecological departures from the "norm", i.e. disjunct or limited habitats, varied biotic sources, and so on.

Having established the credentials of the Southwest in terms of richness and importance of its floras and faunas, let us turn to the question of how riparian ecosystems may be important in perpetuation of these features. In terms of any one group for which such ri-parian ecosystems must be regarded as essential, certainly no question exists that the most im-portant would be fishes. I have already men-tioned that Arizona hosts--or hosted--32 native species and New Mexico 59. Together these total 75 species when combined, no fewer than 6 of which are federally endangered, i.e. Colorado River squawfish (Ptychocheilus lucius), humpback chub (Gila cypha), woundfin (Plagopterus argentissimus), Gila trout (Salmo gilae), Gila topminnow (Poeciliopsis occidentalis), and Pecos gambusia (Gambusia nobilis), plus one species that is threatened, the Apache trout (S. apache). In addition, the New Mexico De-partment of Game and Fish lists 30 species of native fishes as endangered in the state, in-cluding the squawfish, Gila trout, topminnow, and gambusia mentioned above. On a percentage

basis, about half of New Mexico's ichthyofauna is regarded as endangered at the state level, whereas 8 percent of the overall southwestern fauna is federally endangered.

It is obvious that riparian ecosystems are of paramount importance in the survival of native fishes in the Southwest, where the vast majority of the species are riparian (versus lacustrine) in their habitat occupancy. The major threat to the survival of these fishes involves degradation of the required habitats, including lowering of the water table, construction of dams, diversions, and reservoirs, vegetation clearing, pollution, roads, grazing, and the introduction of exotics. This degradation will no doubt continue, for it is partly an outgrowth of man's quest for water and the environments that it fosters. There is little that the dependent biota can do to stem this quest, and man continues to take the aqueous spoils and leave the biota high and dry. Obviously, this approach cannot continue if the ichthyological portion of the rich and important biota of the Southwest is to persist.

Next to fishes, there is no single large group of southwestern vertebrates so dependent for survival on water, that essential and basic element of riparian ecosystems. Yet, there are aquatic plants and invertebrate animals that are just as dependent, including invertebrates. Among the latter are certain mollusks and arthropods, such as Exosphaeroma thermophilum--an endemic crustacean confined to a warm spring run near Socorro, New Mexico. Some animal and plant species are seasonally dependent of riparian ecosystems, such as many amphibians which breed in water. The exact numbers of non-fish species dependent on aquatic habitats in the area has not been determined, but it is significant.

So far, the emphasis on the importance of riparian ecosystems to the biota of the Southwest has concentrated mainly on the question of surface water, as in the cases of fishes and of certain other animals and plants. However, there are other riparian features involved that should also be mentioned, and among the most important is the vegetation characteristic of these ecosystems. A great variety of plants utilize stream courses in the Southwest, including both obligate and facultative species. Typical of the obligates are cottonwoods (Populus spp.), willows (Salix spp.), alders (Alnus spp.), and other broadleaf trees. Facultative species are those that invade stream courses from other habitats, but which may survive without riparian systems. Over 100 kinds of woody plants occur regularly in floodplains in New Mexico, of which about 40% are obligates (Hubbard, ms.).

Riparian plants are biologically important from a number of standpoints. One aspect of their importance is an individual species, for some are restricted in range, numbers, or both. For such species, degradation of the riparian ecosystem could be especially detrimental, even critical to survival. Conversely, for some such species the continued availability of acceptable riparian ecosystems is essential if survival is to continue. Another aspect of importance is at the level of plant assemblages, such as vegetational communities. The matter of communities is especially important, for a great deal of diversity exists among riparian communities in the Southwest (Hubbard, ms.) and this deserves perpetuation. In addition, the assemblage concept is important from the standpoint of revealing evolutionary, ecological, and other biological information, such as any divergence among fragmented populations. There is even a historic (or prehistoric) consideration, in that we may view the broadleaf assemblages of trees and shrubs along many southwestern streams as the major remnant of the ancient Arctotertiary Flora that was dominant in North America 50 to 100 million years ago.

Besides assemblages of plants, aggregations of considerable biological importance are those involving animals as well. Perhaps the aggregation that has attracted most attention recently involves riparian vegetational communities and their attendant birdlife. Although virtually unstudied until recent decades, this biotic aspect of the Southwest has now become better known, and studies have included such streams as the Verde (e.g. Carothers and Johnson, 1973) and Colorado (Ohmart, mss.) in Arizona and the San Juan (White and Behle, 1961; Schmitt, 1976) and Gila (Hubbard, 1971) in New Mexico. All of these systems are extremely rich in breeding birds; for example these two New Mexico river valleys support 16-17% of the entire breeding avifauna of temperate North America over the course of only a few score of miles.

The requirements of these avifaunas involve both the aquatic and the vegetational aspects of riparian ecosystems, but the greater, direct dependence is on the plant communities. Actually, on both the San Juan and the Gila, aquatic habitats other than the river per se are limited, and thus few aquatic species are present. Considering both aquatic and vegetational aspects together

as constituting together riparian habitats, one finds that in the Gila Valley some 25.0% of the 112 breeding bird species are restricted to them, while 24.1% occur in them primarily (Hubbard, 1971). Neither group of bird species, totalling 49.1% of the breeding avifauna, would probably occur in the area in the absence of these riparian habitats. The figures for the 105 breeding species in the San Juan Valley are similar, i.e. 26.5% and 19.4%, or a combined total of 45.9% showing riparian dependence (Schmitt, 1976). In addition, 22.3% of the Gila species and 28.6% of the San Juan species also show some to much utilization of riparian habitats, and several species achieve maximal numbers in them. Clearly, in these two areas the presence of riparian habitats is extremely important, and in essence they double the avian diversity that might otherwise be present. The same degree of importance no doubt pertains elsewhere in the Southwest, and is apparent that riparian ecosystems play a key role in maximizing avian diversity in the region.

Other riparian faunal-plant assemblages seem to have been little studied, but there is no doubt that others will show a strong relationship between biotic diversity and the presence of riparian ecosystems. For example, although there appear to be fewer southwestern mammals than birds with a strong riparian dependence, nonetheless there are certainly some species that do show this, e.g. water shrew (Sorex palustris), Arizona gray squirrel (Sciurus arizonensis), beaver (Castor canadensis), meadow vole (Microtus pennsylvanicus), muskrat (Ondatra zibethica), raccoon (Procyon lotor), mink (Mustela vison), and otter (Lontra canadensis). The same can be said of reptiles, such as various turtles (e.g. Kinosternon spp., Trionyx spp.), green snakes (Opheodrys spp.), water snake (Natrix erythrogaster), and garter snakes (Thamnophis spp.). On the other hand, amphibians show a pronounced dependence on riparian--or at least aquatic--ecosystems, because of the general need of water for reproduction, e.g. in various toads and frogs.

At this point, I believe that it has become readily apparent that riparian ecosystems are of paramount importance in producing and maintaining a large degree of the biotic diversity of the southwestern United States. Although this importance is perhaps most apparent in fishes and best quantified in birds, it is clear that, for many plants and animals, riparian ecosystems are critical for them to flourish or even survive in the region. I am hopeful that more studies will be done to quantify this importance, particularly with reference to the degrees of dependency that exist among biotic elements on these ecosystems and to the niches that are occupied. It goes without saying that the better we understand these aspects, the better we can anticipate the needs of the biota and manage for its preservation. We have already witnessed extremely widespread destruction and modification of riparian ecosystems in the Southwest, mainly as the result of man's activities over the last several decades. As population pressures and the demands on the riparian ecosystem grow, we will be hard-pressed to preserve what is left of the southwestern riparian biota. Yet, if we do not meet the challenge and achieve better preservation, we will have allowed one of the richest of all of the world's temperate floras and faunas to have been diminished.

The time to obtain data and take positive management steps is all too short, but at the same time it is not too late to act. For example, several important examples of riparian ecosystems remain in the Southwest, such as in the lower San Francisco Valley in southwestern New Mexico and southeastern Arizona. This particular tract lies in U.S. National Forest, and with more enlightened management it could provide along over 30 river miles of public land for the maintenance of the very rich lowland riparian biota. At the present time, grazing and off-road vehicles are causing much damage to the tract, which embodies everything about a wilderness or wild river except in terms of management. At higher elevations, more extensive riparian ecosystems lie on public land and are available for preservation, although management again is frequently not accomplishing this.

The sad fact is that even public lands have priorities upon them that are not in the best interest of preserving riparian ecosystems, and changing this outlook for even limited areas is often difficult. On private lands the situation is generally worse, although here and there some degree of preservation has been obtained for some tracts. There is a critical need for a better education of managers of both public and private lands supporting riparian ecosystems as to their importance and values, which range from esoteric to the practical. For example, points of practical importance and value include the role of vegetation in soil retention, effect on climate, and in the harboring species that provide both consumptive and non-comsumptive recreation. These practical uses combine with esoteric considerations to provide a telling argument in favor of better preservation

of our native riparian ecosystems, fragmented and misused as they have become. Hopefully, individuals and agencies will soon join forces to ensure such preservation, which is long overdue and which cannot be delayed much longer.

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Importance of Riparian Ecosystems: Economic Considerations[1]

Kel Fox[2/]

Efforts to preserve riparian habitat must recognize man's growing demands to put this area to other uses. Economic pressures, at conflict with environmental concerns, pose an inevitable threat to vegetation and wildlife. A compromise in the balance of preservation and development must be maintained.

Everyone here today feels the riparian zone is important, or we would not be holding this symposium. Most of you want to preserve it. A few of you will admit, grudgingly, that it needs to be managed. We all can agree that huge areas of riparian habitat have been removed by development-oriented pressures. But few will admit, in this age of environmental concern, that the same economic realities of past decades still pose a threat to much of the remaining habitat. These threats are direct, as, for example, through conversion to farming or residential use, or indirect, as through lowered groundwater levels due to pumping.

These are the general conclusions reached by the staff of the Arizona Water Commission, who helped in the preparation of this paper. Now let's examine them in detail.

When the white man first came to this country, the low deserts were broken by oases along the major rivers. To farm he had to irrigate and the bottom lands were the closest to water. Mesquite bosques and cottonwood thickets were cleared and put into production. Southern Arizona hasn't been the same since, but that's not necessarily bad. The major metropolitan areas, wouldn't be here but for the pioneering efforts of those early farmers.

Clearing the riparian[3/] zone for agriculture is not a historic phenomenon; it still goes on. The bulk of the clearing is of phreatophytes, and most of that is along the Colorado River, below Davis Dam on Indian lands. The Indian reservations along the river in Arizona and California have decreed rights that allow the consumption of 546,000 acre-feet primarily for irrigation. In 1961 there were 80,000 acres of prime arable land on these reservations that were covered with phreatophytes. Clearing will no doubt continue as the tribes develop lands to use their water.

If Senator Kennedy has his way with the Indian water rights bill, 250,000 acres of land on the Gila River Indian Reservation will be irrigated. It is a safe bet that some of the new development will be on areas now in phreatophytes.

[1/] Paper presented at the symposium on Importance, Preservation and Management of Riparian Habitat, Tucson, Arizona, July 9, 1977.

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[3/] In this paper, riparian is used in reference to vegetation which occurs in or adjacent to drainage ways or their floodplains which may be perennial or ephemeral. Phreatophytes are those riparian plants which habitually obtain their water supply either directly or through capillary fringe, from the zone of saturation.

There are concentrations of private land along all of the desert rivers. Much of this land is suitable for agriculture and is subject to clearing.

Farther up the watershed, the higher elevation riparian zone tends to be immune from these pressures. Much of it is locked up in federal administration. It probably will remain unchanged. That small fraction that is in private hands is often too rough, too stony or otherwise unsuited for agriculture. But that doesn't mean it's safe from development pressures.

It's prime country for subdivisions. Pick up a map of a National Forest in Arizona. Those white spots along the major headwater streams are private land, turn-of-the-century homesteads. When the ranchers retire, those places will be up for sale. In a land where small lots in the pines sell for thousands of dollars to greenery-starved desert dwellers, lots in and along a creek bottom, with real running water, are pure gold. And cost as much. Pave the road to the homestead and it's good-by habitat, hello homesite.

Most of the headwater streams are protected from this pressure by ownership and topography. The mid-elevation streams, however, are as a rule, totally exposed. Privately owned bottom lands along Oak Creek, Tonto Creek, the Verde River and the upper San Pedro are now actively being offered for sale and converted into retirement homes.

And what phreatophytes the farmers didn't clear along the Colorado River are subject to clearing or encroachment by the subdivisions sprouting up there for winter visitors.

Water yield improvement projects have taken most of the blame for removal of riparian habitat. However, if you were to analyze the areas cleared, you would find that the large majority of the clearing was a result of direct development pressures; it was the land that was needed for other purposes, rather than the water. Clearing and/or conversion for downstream water yields was much in vogue in the 50's and 60's, however.

The Los Angeles report of the Phreatophyte Subcommittee of the Pacific Southwest Inter-Agency Committee of August 1969 listed nearly two dozen major clearing projects in Arizona. A multitude of benefits were listed, but the common thread was water. The biggest of these was the 42,000 acre project of the Bureau of Reclamation along the Colorado River from Davis Dam to the Mexican boundry.

The project was designed to salvage water to enhance the supply available to the C.A.P. The Bureau surveyed the floodplain in this reach of the river in 1961, identifying 155,000 acres of phreatophytes. Environmental concerns have stalled the project, as it has most of the others, and it is not now being actively pursued. That doesn't mean that clearing of the floodplain won't be accomplished however. Of the nearly 65 percent of surveyed habitat, 98,000 acres, was on private, state, or Indian lands. About half of the proposed clearing program, 20,000 acres was on nonarable Indian lands. All of this is subject to clearing for irrigation or homesites. Only 6,000 acres were in wildlife refuges.

The term "water salvage" has fallen from repute in describing the benefits of these projects, but the intent remains; to make more water available for man's direct use. The U.S. Geological Survey, in a study reported in the Proceedings of the 1968 Arizona Watershed Symposium, estimated annual evapotranspiration of all phreatophytes in Arizona to be about 940,000 acre-feet annually. The monumental study of Ffolliott and Thorud in 1974 indicates that water yield in the riparian habitat in Arizona might be increased as much as 600,000 acre-feet per annum by clearing and conversion. The Comprehensive Framework Study for the Lower Colorado Region estimated 435,000 acre-feet could be salvaged each year under a feasible management program from the phreatophyte habitat. No matter whose estimate you use--it's a great deal of water, a potential increase from 15 to 35 percent of the state's dependable supplies.

Increasing the dependable supplies will become more important as energy costs for pumping and groundwater levels increase. Changes in groundwater law, mandated during this session of the legislature, will no doubt be aimed at reducing groundwater overdraft. This will reduce local supplies still further, which will intensify the demand for increased dependable supplies from other sources. Under these sorts of pressures, environmental considerations will have less importance.

Flood control, or more properly, flood damage reduction, will become more important with time as development increases in or near riparian areas.

Salt cedar, with its prolific growth, will rapidly take over a bare, well watered site. Frequently, that's in the main stem of the channel, and as the stand develops, the channel's conveyance is reduced. Not that high flows, or flood waters, won't get downstream, they do, but at the expense of increased depth of flow and consequent enlargement of the inundated area.

The flows will eventually sweep out the choking vegetation but only after building up to sufficient head and unnecessary levels of damage. Clearing or maintaining a channel thus duplicates Mother Nature's handiwork, and avoids the incremental flood damage.

About a third of those two dozen clearing projects mentioned earlier claimed flood control as one of the project's benefits. The clearing of cottonwoods in the Verde Valley some years back was designed to aid in flood hazard reduction. The phenominal growth of bottom land subdivisions in that Valley may well work to reinstitute such a program.

Environmental pressures have so far worked to set aside the Corps of Engineer clearing projects on the Gila River downstream of Phoenix. Sportsmen and hunter groups joined in that cause, and as a result of their efforts to save dove nesting and roosting cover, they have been denied hunting access to the privately owned portions of the bird's habitat. As more and more hunting areas are denied them, sportsmen may well choose to side with the Corps to work out a compromise solution.

Conservationists are getting more sophisticated with time. They had to, as increasingly they've lost habitat to esoteric causes. Mesquite bosques and salt cedar thickets have died from unseen causes throughout Southern Arizona. Not fire, flood, or pestilence. Not from developers or bulldozers or other direct threats. Still the habitat died.

The cause--a decline in water levels in response to pumpage under developed areas miles distant. Groundwater basins in southern Arizona underlie the valleys from mountain to mountain. The aquifers are quite productive, but recharge is low. This means the cones of influence from a pumping well, or more commonly, hundreds of pumping wells, spread wide, reaching seemingly protected riparian habitat.

The famed San Xavier bosque south of Tucson so died, as have large areas in the thickets along the lower Santa Cruz on the Gila Indian Reservation. It's not done yet, either.

The riparian habitat of the upper San Pedro, site of the proposed Charleston Dam, so successfully opposed by conservationists, is threatened nonetheless. The expansion of Fort Huachuca's mission has brought a subdivision boom to the area. Water level declines are accelerating, the cone of depression rapidly expanding toward the San Pedro.

As I said, conservationists have become more sophisticated, but they've yet to really embrace technology in their fights. The impact of the Fort's expansion in the riparian areas was predicted by our Water Commission in a computer model study of the Fort's groundwater supplies. No one used the information in assessing the proposed expansion. Not that it would have necessarily helped. The move had strong local support. But at least all impacts would have been discussed.

If the march of progress can't be averted, perhaps technology can be used to facilitate the necessary compromises. Recently the Maricopa County Flood Control District acquired a small tract of privately owned riparian habitat along the lower Salt River for mandated mitigation of the impacts of the county flood control program. Will that parcel eventually dry up and die as groundwater

withdrawals continue in the Valley? No one knows--the eventuality wasn't even considered. The Arizona Game and Fish Department intends similar purchases in the area. Should they utilize existing computer models to select tracts? Most assuredly, if they wish to preserve the habitat.

Recreation ranks right next to mom and apple pie as typifying the American. No where else is the pressure on the riparian habitat, and the wildlife it supports, more aptly described by the character from Pogo: "We have met the enemy, and he is us." The physical presence of people is the problem.

Those that sought to protect the eagles at the Orme Dam site enlisted the aid of the river's tubers in the fight. But the tubers themselves are a threat to the eagles, and no doubt one day these bedfellows will part.

The riparian zone is especially attractive to recreationists in this water short land. Demand for this type of recreation exceeds the supply, causing continual pressure on the developed sites, and insuring the certainty of loss of more habitat.

So what does the future hold for riparian habitat when faced with the economic realities of life? Without a doubt, more of the habitat will be lost--there are too many pressures for it to be entirely preserved. Most of the loss will be on private and Indian lands. Here the pressures are felt most keenly, and the management goal is not preservation. Federal lands will probably be preserved to a large extent, although demands for flood control, grazing and recreation will require some concessions.

Society will come to realize that our standard of living cannot be maintained without utilization of all of our resources--today's topic of concern is no exception. Our current preoccupation with wildlands is a luxury we can afford only because the wilderness was subjugated. We must strike a balance today, if only because society did not do so in the past.

Vegetation Structure and Bird Use in the Lower Colorado River Valley[1]

Bertin W. Anderson and Robert D. Ohmart[2]/

Abstract.--Data from riparian communities along the lower Colorado River are used in discussing relationships between the avifauna and the structure of plant communities. Correlations between bird population parameters and vegetation structural characteristics were found to vary seasonally. The mean habitat breadth of all species is narrowest with respect to vegetative structure in winter and broadest in summer; permanent residents occupy the structural types more evenly than visitors. The habitat breadth of various species is greater in summer than winter. Narrower habitat breadths are accompanied by reduced habitat overlap among the species in winter, suggesting that winter is potentially the time of greatest stress. Permanent residents tend to be less specialized with respect to structure than visitors. These facts suggest that since winter requirements are different from but equally as important as breeding requirements, they should receive at least equal attention. The requirements of wintering visitors should receive special attention because they showed a higher degree of habitat specialization than permanent residents.

Since MacArthur and MacArthur (1961) first reported the relationship between breeding bird species diversity (BSD) and foliage height diversity (FHD) much research effort has been expended and quantitative data gathered in an effort to explain relationships between various bird population parameters, such as BSD, and various features in the landscape (e.g. Balda 1969, Cody 1968, Karr 1968, Karr and Roth 1971, Willson 1974). Although of great heuristic value to the theoretician and manager alike, the approach, as Balda (1975) stated, is too impersonal; that is, it does not consider the biology of individual species. This problem has been successfully attacked in part by analyzing the vegetation in the vicinity of singing males during the breeding season (Anderson and Shugart 1974, Conner and Adkisson 1977, James 1971, Whitmore 1975 a, b). These investigators have successfully applied multivariate analyses to the problem of habitat selection. Such analyses have an advantage of reducing problems associated with data interpretation, although multivariate axes are often difficult to precisely verbalize (Shugart et al. 1975). While studies of the vegetation around individual singing males undoubtedly provide valuable information concerning the characteristics of the breeding environment, it is only a small step toward understanding species' habitat requirements and there are definite problems associated with the technique. Anderson (1974) found that sub-adult male grosbeaks (Pheucticus ludovicianus and P. melanocephalus) tended to establish territories in suboptimal portions of the habitat. Furthermore, several of these sub-adults failed to acquire mates although they sang almost constantly. The suboptimal portions of the habitat often included parks and roadsides, and therefore, these birds were much more easily found and observed than the adult males which tended to inhabit denser thickets. Inclusion of these males in greater proportion than their occurrence in the population could result in misleading conclusions concerning their breeding habitat requirements. Misleading conclusions could also be reached in spatially restricted studies for many other species, especially polygynous species such as the Long-billed Marsh Wren (Cistothorus platensis)

1/ Paper presented at the symposium on Importance, Preservation and Management of Riparian Habitat, Tucson, Arizona 9 July 1977.

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(Verner and Engelsen 1970), Yellow-headed Blackbird (Xanthocephalus xanthocephalus) (Willson 1966), Red-winged Blackbird (Agelaius phoeniceus) (Holm 1973, Linsdale 1938), and Dickcissel (Spiza americana) (Harmeson 1974, Martin 1971, Zimmerman 1966). In the southwest desert there is an additional problem--several species breed in a number of vegetative types over a relatively long period of time (four or five months). Obviously, analysis should include males proportionate to their occurrence in all vegetative types throughout the breeding season. Breaking the analysis into several spatial and temporal components perhaps would be most appropriate.

Seasons other than the breeding period have received little attention even though they may be equally or more important than the breeding season. Fretwell (1972) provided cogent arguments to the effect that quality of the wintering habitat is critically important to survival of the breeding population and that populations will decrease despite abundant high quality breeding habitat when wintering habitat is poor. Shugart et al. (1975) presented two discriminant functions for seven species from data gathered in fall and winter, but such studies are rare.

Another factor which may affect the way a habitat is utilized by a species, but which is often neglected, is population size. Population sizes, in turn, are affected by a number of biotic and climatic factors. Some measure of the population size should be related to statements concerning species' requirements. All of these factors can best be studied and understood by censusing large areas several times a year for a period of years. Unfortunately, such studies require a relatively large staff and are, therefore, costly; but if quality data are the result, such studies may prove to be the most efficient and inexpensive in the long run.

In this report we evaluate the importance of vegetative structure at the habitat level to birds in the valley of the Colorado River from Davis Dam to the Mexican boundary, about 443 km. The relationship of entire avian communities, guilds, and individual species to structure of the vegetation will be discussed on a seasonal basis. The importance of season (especially winter), climate, and population sizes will be presented. Although our data are suited for multivariate analyses, we are not prepared to present the results of such analyses as they relate solely to structure at this time. Such analyses are underway and preliminary results are consistent with our comments here.

In defining habitat we concur with Whittaker et al. (1973) that terms such as niche and habitat should be stabilized, and we follow their recommendation in considering the niche as an intracommunity variable and the habitat as a broader concept usually encompassing more than one community. Communities, in this report, refer to fairly homogeneous areas with respect to dominant vegetation and structure and range in size from 10 to 40 ha. Niche requirements, as opposed to habitat requirements, are not presented here because of space limitations. Similarly, data concerning dietary preference and feeding behavior must be omitted from this report but will be available at a later date.

CORRELATIONS

The relationships between bird population parameters and the various vegetative parameters were examined with regard to the spatial and temporal dimensions of the environment. Further, the diversity measures are of all birds and not just breeding birds and are used to discuss the value of vegetative structure in evaluating the wildlife use values of an area. Each year was divided into five seasons: winter included December, January and February; spring included March and April; summer included May, June and July; late summer included August and September; and fall included October and November.

Our study area encompasses about 4,828 km^2 between Davis Dam, located on the Nevada-Arizona border, and the Mexican boundary south of Yuma, Arizona. The riparian vegetation was divided into six community types based on the dominant plant species and into six structural types based on the vertical profile of each community. Methodology employed for determining structure and for censusing birds is discussed elsewhere in these proceedings (Anderson, Engel-Wilson, Wells and Ohmart).

Vegetation Parameters

Since the data did not fit a normal curve, correlations were determined using the nonparametric Kendall rank correlation (Sokal and Rohlf 1969). Correlations between structural variables are significant and positive in four cases and significant and negative in one instance out of ten comparisons (Table 1).

Bird Density and Vegetation Structural Parameters

Bird density in winter correlated with vegetation at the 1.5 to 3.0 m level (Table 2).

Table 1.--Correlations between vegetative structural characteristics in the riparian vegetation along the lower Colorado River Valley.

	Height			Total Relative Density	FHD
	0-0.6 m	1.5-3.0 m	>4.5 m		
0-0.6 m	-	-0.076	-0.42**	0.02	-0.12
1.5-2.0 m	-	-	0.49**	0.67**	0.11
>4.5 m	-	-	-	0.54**	0.35*
Total	-	-	-	-	0.02
FHD	-	-	-	-	-

* and ** significant at $p<0.05$ and <0.005 respectively.

Table 2.--Correlations between bird population parameters and vegetation parameters at five seasons in the lower Colorado River Valley.

Relative Density of Vegetation at	Season: Dec 1974 Jan 1975 Feb	March April	May June July	Aug Sep	Oct Nov
BIRD DENSITY					
0.6 m	-0.02	-0.25	-0.36*	-0.22	0.18
1.5-3.0 m	0.10	0.05	0.42*	0.31	0.04
>4.5 m	-0.16	0.14	0.52*	0.18	0.12
Total	0.16	0.04	0.39*	0.26	0.03
FHD	0.04	0.13	0.02	-0.18	0.19
BSD					
0.6 m	-0.40*	-0.23	0.48*	0.01	-0.10
1.5-3.0 m	-0.10	-0.39*	-0.18	0.51**	0.25
>4.5 m	-0.14	-0.13	-0.12	-0.59**	0.43*
Total	-0.19	-0.32*	-0.04	-0.74**	0.16
FHD	0.29*	0.11	0.09	0.03	0.63**
BSD WITH 10% DOVES					
0.6 m	-0.16	-0.21	0.17	-0.02	-0.01
1.5-3.0 m	-0.02	-0.25	0.03	-0.35*	0.14
>4.5 m	0.23	0.15	0.11	-0.52*	0.23
Total	-0.07	-0.18	-0.04	-0.35*	0.09
FHD	0.38*	0.09	0.43*	-0.25	0.45**
SPECIES					
0.6 m	-0.32*	-0.30*	-0.24	0.04	-0.12
1.5-3.0 m	-0.37*	-0.34*	0.20	-0.14	-0.02
>4.5 m	0.00	-0.17	0.17	-0.28	0.22
Total	-0.44**	-0.35*	0.22	-0.20	-0.07
FHD	0.32*	0.09	0.31*	-0.13	0.58**

* and ** significant at $p<0.05$ and <0.005 respectively.

This is at least partly because honey mesquite stands with volume at this level are correlated with mistletoe. The presence of mistletoe adds another dimension to the habitat and supports several species which are nearly absent elsewhere. In spring, bird densities were relatively high in several structural types, thus density was not correlated with any structural parameter. Spring is a period of transition--winter residents are still present and summer residents

are returning. In the summer, after winter residents have departed, the greatest numbers of birds were found in areas with the greatest total vegetation. Late summer is another transition period; many summer residents depart and wintering species arrive. In fall the greatest numbers of birds were found in relatively open areas (low total density of vegetation) as well as in areas with volume at the intermediate levels. Explanations of this are too numerous and conjectural to present here.

BSD and Vegetation Structure

In winter there was a significant negative correlation between volume of 0 to 0.6 m and BSD (Table 2). Areas with greatest vegetative volume at the lower levels tended to be dominated numerically by White-crowned Sparrows (Zonotrichia leucophrys). There was a positive correlation in winter with FHD. In the spring BSD was significantly negatively correlated with the densest areas with relatively dense vegetation at 1.5 to 3.0 m. In the summer BSD was significantly correlated with density of vegetation in the lower layer (0 to 0.6 m). Doves in summer in the more lush areas have such overwhelming numerical dominance that BSD in such areas is suppressed. In fall, after many doves had migrated, BSD and FHD were positively correlated. Removing 90 percent of the doves from the data revealed a correlation between FHD and BSD in winter, summer, and fall but not in spring or late summer. The number of species is correlated with FHD in winter, summer, and fall. Number of species and BSD are correlated with each other at all seasons (Anderson and Ohmart, unpubl. data).

Comparison of Years

Correlations between the bird parameters and structural features were nearly the same each year (Table 3). The greatest deviation was found in summer 1976 when total bird density was significantly correlated with FHD, contrary to findings in 1975. This may have occurred because doves, which are most numerous in areas of low or moderate structural diversity, were at least 40 percent fewer in numbers in most areas in 1976.

In summary, it would appear that dense vegetation is more important to birds in the early summer than at other times of the year. This is generally true, but the presence of up to 1500 doves per 40 ha tends to exaggerate the importance of dense vegetation. Similarly, because of large numbers of White-crowned Sparrows and Phainopeplas (Phainopepla nitens), the reaction of many species to sparse vegetation is obscured in the winter. White-crowned Sparrows are primarily granivorous and are found in relatively open areas, whereas Phainopeplas are found wherever there is mistletoe, which is most abundant in areas of moderate density.

BSD was not correlated with FHD in summer, but this is misleading for the excess of doves in summer masks the real diversity of birds found in areas where doves predominate. This relationship is revealed by using only 10 percent of the doves in calculating BSD or by simply considering the number of species involved. By using either of the above alternatives, the data suggest a correlation in summer between BSD and FHD.

The correlation between BSD and FHD in this study does not provide as good a fit to a regression line as in a number of other studies, thus indicating that along the lower Colorado River only a relatively small part of the observed diversity is due to structural complexity. That it is significant in three of five seasons, however, suggests that structural complexity does have important management implications. Obviously, BSD must be evaluated within the context of other population parameters, such as the number of species and the density of vegetation.

HABITAT BREADTH BY STRUCTURE OF VEGETATION

The extent to which each species occupies the various structural types of vegetation is referred to here as a species' habitat breadth by structure (HB_s). This is calculated by $HB_s = -\Sigma p_i \log_e p_i$ where p_i is the proportion of individuals found in the ith structural type. This parameter is independent of the distribution in which we designate habitat breadth for vegetative type (HB_v). For example, a species equally abundant in all six structural types in cottonwood-willow communities would have the same HB_s as one found in equal numbers in all dominant vegetation of all structural types. The former would, of course, have HB_v of 0.0 while HB_v of the latter would be $\log_n$ of 6 or 1.8 (based on six dominant community types in riparian vegetation). HB_s and HB_v are calculated for each species and the means for all species occurring at densities of at least 1/40 ha each month and for each season are calculated.

Mean HB_s

Mean HB_s for each season (fig. 1) reveals four things of potential ecological importance as related to seasons. First, high summertime values in mean HB_s are followed by a lower mean in the cooler time of year. Second, the smallest mean HB_s occurred in the winter of 1974-75. Third, visiting species tend to have lower mean HB_s than permanent residents.

Table 3.--Correlations between bird population parameters and structural features in summer 1975 and 1976 along the lower Colorado River Valley.

	Height			Total Relative Density	FHD
	0-0.6 m	1.5-3.0 m	>4.5 m		
DENSITY					
1975	-0.36*	0.42**	0.52**	0.39**	0.02
1976	-0.55**	0.44**	0.67**	0.47**	0.36**
BSD					
1975	0.48**	-0.18	-0.12	-0.04	0.09
1976	0.49**	-0.22	-0.39*	-0.15	-0.15
BSD WITH 10% DOVES					
1975	0.17	0.03	0.11	-0.04	0.43**
1976	0.04	0.09	0.31	0.17	0.34*
SPECIES					
1975	0.24	0.20	0.17	0.22	0.31*
1976	0.15	0.20	0.28*	0.24	0.24

* and ** significant at $p<0.05$ and <0.005 respectively.

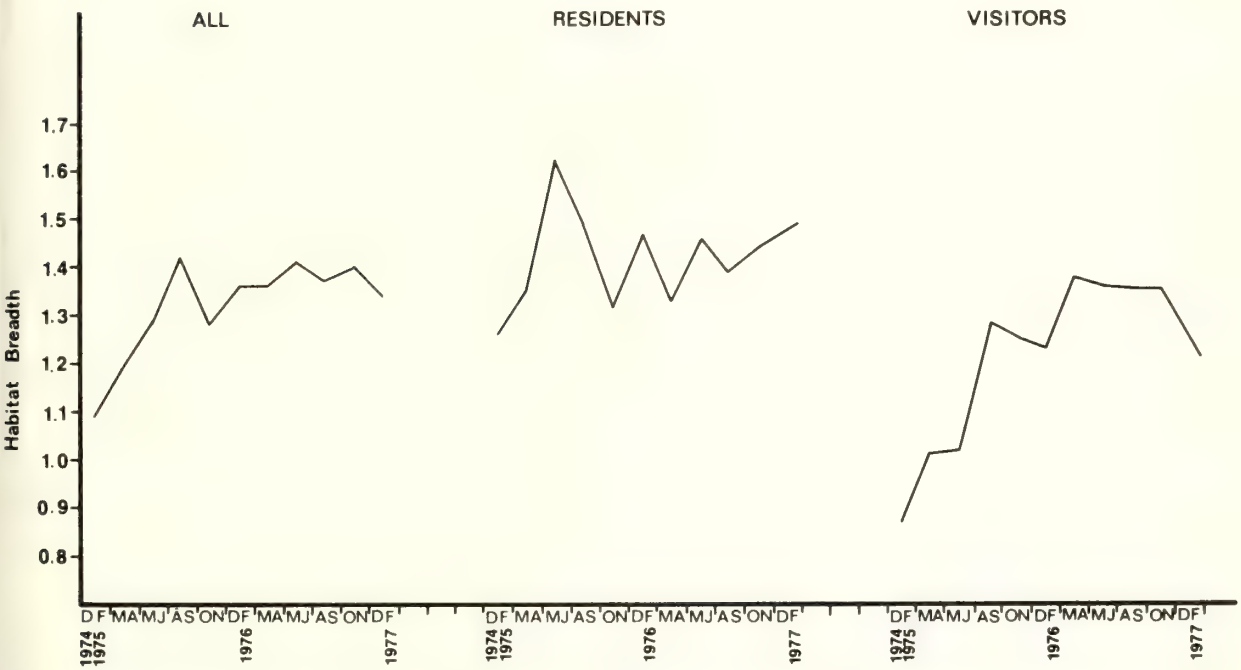


Figure 1.--Seasonal changes in mean habitat breadth for all species at various seasons along the lower Colorado River.

Finally, HB_s was not reduced in fall 1976; in fact, it increased for permanent residents.

The relatively low mean in cooler seasons coincides with the time of year when productivity is lowest. As insects decline in number, they probably become more restricted in their distribution (Raitt and Pimm 1976); this disjunct distribution is probably mirrored by the restricted distribution of insectivorous birds which tended to have narrower HB_s. Similarly, the patchy distribution of seeds in the sparser

areas is reflected by the relatively narrow HB_S of wintering seed eating birds.

The low HB_S in winter 1974-75 appears to be accounted for in that the winter was significantly colder with more days of frost and was windier than subsequent winters (Anderson and Ohmart, MS[3]/). We predict that habitat breadth will increase in a given season only if resources become so abundant that consumption is limited more by the birds' ability to harvest than by competition during the season or if regulation during that season is by predation (Anderson and Ohmart, MS[3]/). Insects were probably less abundant (Raitt and Pimm 1976) and this, in addition to the fact that the colder windier conditions required more energy per day per bird, appears to have restricted HB_S during that period. The subsequent winter was milder than average and mean HB_S was correspondingly higher. Visitors tend to have narrower mean HB_S than do permanent residents, indicating that they are more sensitive to features of the vegetation structure on the average than permanent residents (see below).

Unusually heavy rainfall in September followed by above average fall temperatures may have resulted in greater insect productivity than normal and allowed expanded HB_S in the fall of 1976.

In summary, these data indicate that the use of structure is not static. Not only is there variation in mean HB_S from species to species, but from season to season and year to year, reflecting seasonal and annual differences in climate and other factors. In addition, permanent residents and visitors adapt to vegetation structure in different ways. HB_S and HB_V and their ecological significance are discussed at greater length, especially with respect to the theory of competition in Anderson and Ohmart (MS[3]/).

FORAGING GUILDS AND VEGETATION STRUCTURE

The Flycatcher Guild

In summer the Ash-throated Flycatcher (Myiarchus cinerascens) was the numerically dominant flycatching species in all structural types and was fairly evenly distributed with somewhat greater density in structural type II (Table 4). The Western Kingbird (Tyrannus verticalis) was found most frequently in type II. The Wied Crested Flycatcher (Myiarchus tyrannulus) was most numerous in type I. The mean HB_S for this group in the summer was 1.435.

In winter the Say Phoebe (Sayornis saya) was the only flycatcher occurring in densities of at least 0.5 per 40 ha. Its HB_S was 1.363 which is 5.7 percent smaller than the summer average for the group.

Medium-sized Insectivores

In summer a group of six medium-sized insectivores were present at densities of at least 0.5 per ha. Among them, the Blue Grosbeak (Guiraca caerulea), Cactus Wren (Campylorhynchus brunneicapillus), and Northern Oriole (Icterus galbula) had relatively large HB_S (Table 4). The Yellow-breasted Chat (Icteria virens) was intermediate and the Summer Tanager (Piranga rubra) and Yellow-billed Cuckoo (Coccyzus americanus) were specialists, being found most extensively in structural type I. The average HB_S for the group was 1.413.

The Cactus Wren is the only member of this group present in winter. Its winter HB_S, 1.695, is larger than the average for the group in summer but is about 5 percent smaller than its own summer HB_S.

Ground Feeders

In the summer the ground feeders included three permanent resident species (Table 4). All were rather evenly distributed throughout the structural types of vegetation (Table 4). The average HB_S was 1.650.

In winter the three ground feeders were somewhat less general in their distribution (Table 4). The Abert Towhee (Pipilo aberti) was found most frequently in structural type I. The average HB_S was about 5 percent smaller than in summer.

Small Insectivores

In the summer there were three insectivorous species weighing less than 15 g (Table 4). All three (two were permanent residents, one visitor) were widely distributed among the structural types (Table 4) as reflected by their mean HB_S of 1.694. The Lucy Warbler (Vermivora luciae) was numerically dominant in types I and II. The Verdin (Auriparus flaviceps) was numerically dominant in all the other types. In winter the number of small insectivores increased to five. Among them the Yellow-rumped Warbler (Dendroica coronata),

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3/ Manuscript in preparation discussing seasonal changes in habitat breadth and overlap among birds along the lower Colorado River.

Table 4.--Densities (N/40 ha) of various birds by vegetation structure for winter 1975-76 and summer 1976.

Species Groups	Structure Type I	II	III	IV	V	VI	HB_S	J
Flycatchers								
Winter								
Say Phoebe	1.00	2.67	3.00	0.60	-	0.50	1.37	0.765
Summer								
Ash-throated Flycatcher	7.00	16.00	11.25	11.60	7.75	11.20	1.76	0.982
Wied Crested Flycatcher	4.00	1.33	1.25	0.20	-	-	1.05	0.586
Western Kingbird	0.50	4.50	1.80	0.80	0.50	1.50	1.50	0.837
Medium-sized Insectivores								
Winter								
Cactus Wren	1.00	0.33	1.00	0.80	0.33	0.50	1.70	0.949
Summer								
Northern Oriole	10.50	18.33	12.75	8.40	3.75	4.20	1.65	0.921
Summer Tanager	16.00	3.00	2.50	0.40	-	-	0.82	0.458
Blue Grosbeak	7.00	10.33	9.00	6.40	5.50	7.40	1.77	0.988
Cactus Wren	1.00	2.00	1.75	1.40	0.75	1.80	1.74	0.971
Yellow-billed Cuckoo	3.00	1.67	1.75	0.20	-	-	1.16	0.647
Yellow-breasted Chat	6.50	7.33	3.50	2.00	0.25	-	1.33	0.742
Ground Feeders								
Winter								
Abert Towhee	22.00	6.67	4.00	4.20	2.00	6.75	1.49	0.831
Crissal Thrasher	1.00	0.33	1.67	1.60	2.00	2.25	1.68	0.938
Gambel Quail	-	2.67	5.00	6.20	7.00	2.75	1.54	0.860
White-crowned Sparrow	-	-	0.67	18.00	10.33	14.00	1.14	0.636
Sage Sparrow	-	-	-	2.00	3.33	0.75	0.95	0.535
Summer								
Abert Towhee	14.50	29.33	50.00	15.80	11.50	11.40	1.69	0.943
Crissal Thrasher	-	4.33	5.00	4.20	4.25	2.20	1.24	0.691
Gambel Quail	0.50	20.00	10.25	15.40	21.00	18.00	1.61	0.898
Small Insectivores								
Winter								
Verdin	5.00	0.33	3.33	4.00	3.00	10.25	1.54	0.859
Black-tailed Gnatcatcher	1.00	1.00	4.67	6.81	5.67	8.00	1.58	0.882
Brown Creeper	4.00	5.00	1.00	0.40	-	1.00	1.27	0.882
Ruby-crowned Kinglet	69.00	17.67	15.00	9.00	5.67	9.75	1.38	0.770
Yellow-rumped Warbler	62.00	10.33	10.33	3.20	3.00	6.00	1.16	0.647
Bewick Wren	8.00	-	1.67	1.60	1.33	1.50	1.28	0.714
Summer								
Verdin	4.50	14.33	18.50	22.80	13.75	16.80	1.71	0.954
Lucy Warbler	21.50	26.67	14.00	14.40	10.25	5.20	1.68	0.938
Black-tailed Gnatcatcher	8.50	3.00	3.00	7.40	6.50	2.80	1.69	0.943
Woodpeckers								
Winter								
Ladder-backed Woodpecker	9.00	6.33	6.00	3.00	1.67	2.00	1.63	0.910
Common Flicker	5.00	5.00	3.33	1.60	1.33	0.75	1.60	0.893
Summer								
Gila Woodpecker	8.50	6.37	2.25	1.20	0.75	1.20	1.43	0.798
Ladder-backed Woodpecker	12.00	13.33	6.75	5.40	2.75	4.40	1.66	0.926
Common Flicker	2.00	3.00	1.25	0.20	-	-	1.14	0.639

Brown Creeper (Certhia familiaris) and Ruby-crowned Kinglet (Regulus calendula), all visitors, were the most specialized (Table 4). The Black-tailed Gnatcatcher (Polioptila melanura) and Verdin, both permanent residents, were the structural generalists. The mean HB_S of the group was 18 percent lower than in the summer (Table 4).

Woodpeckers

The Ladder-backed Woodpecker (Picoides scalaris) is the most generalized woodpecker both in winter and summer (Table 4). The Gila Woodpecker (Melanerpes uropygialis) is the most specialized in winter. The Flicker is intermediate for both seasons. The average HB_S for the group was the same in summer and winter (Table 4). No visitors occurred in either season.

SPECIES OVERLAP IN USE OF STRUCTURE

Because two species have similar HB_S does not necessarily mean that the overlap in habitat breadth by structure (R_O) is 100 percent. We quantified overlap between pairs of species using Horn's (1966) formula. The method is discussed more fully elsewhere in these proceedings (Anderson, Engel-Wilson, Wells, and Ohmart). The overlap in the five groups of ecologically similar species was greatest in the summer (Table 5). Mean overlap of all of these species was significantly smaller in winter than in summer.

The analysis of HB_S and habitat overlap by structure (R_{O_S}) points out several significant ecological considerations. One is that winter and summer visitors tend to be more specialized with respect to their use of vegetation structure as well as the dominant types of vegetation (Anderson and Ohmart, MS[3]) than permanent residents. Both visitors and permanent residents tend to be more specialized in the use of vegetative structure in the cool times of the year--woodpeckers being the exception. This suggests that winter requirements may be different from summer requirements. Our findings corroborate Fretwell's (1972) prediction that winter residents in a given area will have larger populations and be more specialized than the local populations of permanent residents. In the Colorado River Valley winter residents do tend to have the largest populations (Anderson and Ohmart, MS[3]) but are rather habitat specific. This indicates that if these rather restricted habitat types are destroyed, a relatively large breeding population from some more northerly area could be reduced or eliminated.

STRUCTURAL SPECIALISTS

Some species prefer certain structural characteristics within a particular community type; a few seem to be more specialized as to structure and less specialized with regard to the type of dominant vegetation. For this analysis we have used the number of each species in the structural types in each dominant vegetative type and calculated simple correlations between the bird numbers and particular structural characteristics. The species we attempted to find were those preferring, for example, dense vegetation at 3.0 m and not discriminating between different kinds of dominant vegetation. A structural specialist found only in type I cottonwood-willow would not qualify as an overall structural specialist but would be a specialist in two dimensions--structure and dominant vegetation.

Some Simple Cases

The Abert Towhee showed a slight, but not statistically significant, preference in summer for dense vegetation. In winter, however, the correlation is significant (Table 6). The towhee cannot be considered a structural specialist because it is also fairly common in relatively sparse vegetation, but it does seem to show a preference for dense vegetation and this correlation becomes stronger in winter.

The Summer Tanager shows a significant (Table 6) correlation with vegetation taller than 9 m. Although much of the vegetation above this height is cottonwood or willow, when salt cedar or other vegetation is available, the tanager uses it.

The Western Kingbird also shows a preference for tall vegetation (Table 6). Unlike the tanager which is restricted mainly to the denser area, the kingbird occurs in areas where there are only a few tall trees but reaches peak numbers in areas where tall trees are dense. The Ruby-crowned Kinglet, a winter visitor, reaches peak densities in the tallest vegetation (Table 6). It cannot be considered a structural specialist, however, because it also accepts other structural types including rather sparse vegetation completely lacking in tall trees.

The three woodpeckers (Ladder-backed, Gila, and Common Flicker) are all significantly correlated with foliage greater than 9 m (Table 6). The Ladder-backed Woodpecker, while showing a preference for areas with taller trees, was also quite common in some structural types totally lacking in tall trees. The other two, however, can be considered structural specialists.

able 5.--Overlap in use of vegetation structure by various groups of species in summer and winter along the lower Colorado River.

	Overlap Matrices					Mean R_o	
						Summer	Winter
lycatchers							
Summer	WK *	WF					
Ash-throated Flycatcher	0.963	0.757					
Western Kingbird	-	0.621					
Wied Crested Flycatcher	-	-				0.780	
Winter							
Say Phoebe							0.000
edium-sized Insectivores							
Summer	ST	BG	CW	YBCu	YBCh		
Northern Oriole	0.744	0.974	0.968	0.899	0.939		
Summer Tanager	-	0.676	0.602	0.944	0.868		
Blue Grosbeak	-	-	0.955	0.837	0.863		
Cactus Wren	-	-	-	0.745	0.802		
Yellow-billed Cuckoo	-	-	-	-	0.962		
Yellow-breasted Chat	-	-	-	-	-	0.833	
Winter							
Cactus Wren							0.000
mall Insectivores							
Summer	V	LW					
Black-tailed Gnatcatcher	0.933	0.954					
Verdin	-	0.892					
Lucy Warbler	-	-				0.926	
Winter	YW	BG	V	BW	BC		
Ruby-crowned Kinglet	0.893	0.689	0.591	0.700	0.790		
Yellow-rumped Warbler	-	0.728	0.576	0.714	0.219		
Black-tailed Gnatcatcher	-	-	0.926	0.931	0.288		
Verdin	-	-	-	0.869	0.144		
Bewick Wren	-	-	-	-	0.000		
Brown Creeper	-	-	-	-	-		0.798
round Feeders							
Summer	CT	GQ					
Abert Towhee	0.938	0.885					
Crissal Thrasher	-	0.971					
Gambel Quail	-	-				0.931	
Winter	CT	GQ	WS	SS			
Abert Towhee	0.659	0.892	0.509	0.527			
Crissal Thrasher	-	0.833	0.808	0.825			0.748
Gambel Quail	-	-	0.928	0.928			
White-crowned Sparrow	-	-	-	-			
Sage Sparrow	-	-	-	-			0.748
ean of all R_o's						0.862(.115)	0.602(.312) p<0.01

Abreviation for the species in the vertical column, e.g. WK=Western Kingbird; V=Verdin;etc.

The relationship between the Yellow-reasted Chat and structure is more complex. he chat, a summer visitor, seems to prefer reas with vegetation at both 3 m and >9 m Table 6). It occurs in very low numbers or s absent from areas lacking at least moderate evelopment in these two layers and is clearly associated with vegetation of a specific structural configuration.

The Crissal Thrasher (Toxostoma dorsale), a permanent resident, seems to prefer areas which are dense at 3 m but which lack vegetation above 9 m. The line of prediction (Table 6)

Table 6.--Species which show preferences for vegetation structure along the lower Colorado River.

Species	Correlated with relative volume at	Season	Regression Equation	Correl. Coef.	Prob. of assoc. being due to chance
Abert Towhee	Total Volume	S	Y=15.65x+8.51	0.375	1.64<0.100
Abert Towhee	Total Volume	W	Y=9.86x-0.62	0.580	2.38<0.050
Yellow-breasted Chat	3m+≥9m	S	Y=25.54x-1.92	0.752	4.63<0.001
Summer Tanager	≥9m	S	Y=21.94x+0.48	0.731	4.58<0.000
Crissal Thrasher	3m-≤9m	S	Y=24.75x+2.11	0.726	3.33<0.000
Ruby-crowned Kinglet	≥9m	W	Y=17.30x+7.09	0.910	5.22<0.001
White-winged Dove	3m+4.5m+9m	S	Y=3.43x-10.36	0.782	3.58<0.002
Mourning Dove	3m+4.5m+9m	S	Y=316.30x+50.05	0.547	2.51<0.020
Yellow-rumped Warbler	0.1-0.6m	W 1974-75	Y=266.74x-41.83	0.599	2.32<0.050
Yellow-rumped Warbler	≥9m	W 1975-76	Y=93.09x+3.09	0.913	3.76<0.002

was obtained by subtracting the relative volume greater than 9 m from that at 3 m. Since thrashers occur commonly but in somewhat reduced numbers in vegetation with other structural configurations, they were not considered structural specialists.

Some Complex Examples

The White-winged Dove (Zenaida asiatica) and the Mourning Dove (Zenaida macroura) showed very complex relationships with vegetative structure. Both species reached greatest nesting densities in areas with relatively dense vegetation at 3.0, 4.5, and 6.0 m and a lack of vegetation above 9 m (Table 6). The highly significant regression line was obtained by subtracting the relative volume above 9 m from the sum of the relative volumes at the other three layers. The White-winged Dove was more of a specialist in this regard as nesting densities are low in other structural types. Mourning Doves on the other hand reached moderate densities in other types, too. The White-winged Dove seemed to suffer less nest predation under these conditions of vegetation structure (Butler 1977).

A Special Case

In winter 1975-76 Yellow-rumped Warbler densities were found to be significantly correlated with the volume of vegetation 0 to 0.6 m (Table 6); the following winter there was a significant positive correlation with volume above 9 m but not with volume at 0 to 0.6 m ($r = 0.2$, $p<0.05$). While this may appear to defy explanation, it is apparently related to climate. In the winter of 1975-76 the Yellow-rumped Warbler population was about the same in type I but much reduced in sparser areas lacking tall vegetation. It seems possible that the areas with tall trees are in fact preferred; but when the limited amount of this structural type is filled, the excess goes to the sparser areas. A constellation of factors including climate and food supply are probably important in determining the number of Yellow-rumped Warblers which move into and winter in the Colorado River Valley.

The Yellow-rumped Warbler was considered a structural specialist in winter. Obviously, erroneous conclusions could be drawn if only one year's data or data from only one community type had been used in analyzing Yellow-rumped Warbler wintering habitat requirements.

Significantly, of the nine species which show structural preferences, six are visitors and three are permanent residents in spite of the fact that the number of species of permanent residents and visitors are present in about equal numbers. One of the permanent residents showed a preference only in winter. All of the species showing greatest structural preference are visitors.

CONCLUSIONS

From data presented here, correlations between bird population parameters and vegetatio structural characteristics vary seasonally in the lower Colorado River Valley. Although the relationships to structure were considered on a rather coarse-grained level in this report, the same trends are apparent at finer levels of distinction as well as for other vegetative characteristics (Anderson and Ohmart, unpubl. data). Habitat breadth is narrowest in winter and broadest in summer; permanent residents occupy the habitat more evenly than visitors. R_O of the various species are greater in summer than winter. Narrower HB_S and reduced Ro_S in winter suggest that winter is potentially the time of greatest stress. Permanent resident tend to be less specialized in structural

reference than winter visitors. These facts ave management implications. First, since inter requirements may be different but of qual or greater importance than summer breeding) requirements, they should receive t least equal attention. The requirements of intering visitors should receive particular ttention for they tend to be specialists with arge populations. If the portion of the abitat in which they specialize is destroyed r damaged, its loss could mean total loss of breeding population. Finally, the require- ents of summer residents also need special ttention as they too tend to be specialized-- lthough probably not to the same degree as inter visitors.

ACKNOWLEDGEMENTS

We wish to thank the many field biologists ho have helped in collecting data. We are rateful to Jack Gildar for computerizing the ata. The efforts of the secretarial staff n typing early drafts and Penny Dunlop and atherine Hildebrandt in typing the final anuscript are greatly appreciated. Linda heney kindly prepared the illustrations. e thank Jane Durham, Jake Rice, James Bays, nd Jeannie Anderson for critically reading arly drafts of the manuscript. The research as funded through grant number 14-06-300-2415 rom the U.S. Bureau of Reclamation.

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A Riparian Case History: The Colorado River[1]

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Abstract.--Historically to present cottonwood communities have declined in abundance along the lower Colorado River to the condition that the future of this natural resource is precarious. Avian species showing strong specialization to cottonwood communities may be extirpated should the cottonwood community be lost from the river. Only through the concern and action by responsible agencies can we assure the persistance of this natural resource.

An overview of the ecological changes that have occurred on the lower Colorado River can be obtained by selecting an important plant community and examining its condition through time. To adequately describe the lower Colorado River riparian ecosystem and discuss the ecological changes from our first written records (1539) to the present is not possible within the space constraints of these proceedings. Therefore, we have elected to analyze an important plant association in this ecosystem and examine its distribution from the early 1600's to present. Although we refer to this association as the cottonwood (Populus fremontii) community, it frequently occurs mixed with such species as willow (Salix gooddingii) and/or screwbean mesquite (Prosopis pubescens) and infrequently with such species as arrowweed (Tessaria sericea), honey mesquite (Prosopis juliflora) and recently the introduced salt cedar (Tamarix chinensis).

Some avian species that inhabit this community along the lower river appear to be very specific in their habitat requirements (Anderson and Ohmart 1975). Consequently, as the unit area of this plant community changed, in all probability, so did the abundance of these habitat-specific species. By examining this biotic community from past to present, we gain an appreciation of the areal changes that have occurred and can make better predictions as to the future of this community type. This analysis should be helpful in providing impetus for management decisions relative to the cottonwood community along the river.

It is tempting to speculate that early man lived in harmony with his environment and that the earliest descriptions of the plant communities along the lower Colorado River reflect the natural environment unaltered by man. Because of space constraints, we will assume this is true, but it must be kept in mind that man could have had a strong influence on his environment through burning and other habitat alterations, especially at the local level.

If we assume that the Indians did not drastically modify the environment, we can examine alterations, classed as natural or unnatural, brought about by the Spaniards and later the Anglo-Americans. It has been argued that man is a natural part of his environment and that alterations brought about by his activities are as natural as changes produced by other animal activities (Malin 1956). This is academic when it is considered that natural resources are finite, and regardless of the causes of degradation and loss, if we value these resources, then we must preserve and manage them for their continued existence.

1/ Paper presented at the symposium on Importance, Preservation and Management of Riparian Habitat, Tucson, Arizona, 9 July 1977.

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INDIANS AND SPANIARDS

Long before European man viewed the waters of the lower Colorado River, a variety of Indian cultures evolved and became established along its banks. However, they left no written record, so Spanish documents provide our earliest information about the region. The Spaniards claimed the region of the lower Colorado for over 250 years. Interested in converting the Indians to christianity, discovering a land passage to the South Sea (Gulf of California) and acquiring mineral wealth, their missionary-military expeditions explored the Pimeria Alta. These early explorers left diaries often containing descriptive information on the areas they traveled.

In February of 1699, Father Eusebio Francisco Kino, accompanied by Juan Mathes Manje, an excellent diarist, viewed the junction of the Gila and Colorado rivers from a distance of 15-18 miles. Manje wrote: "...we plainly saw at a distance of six or seven leagues [1 league = 2.5 miles] the banks and junction of the very great Rio Colorado with this one [the Gila], grown with dense groves with new leaves and although we saw it at a long distance the groves appeared to us to be more than a league wide,..." (Bolton MS 203:20).

Kino, a student of both the Faith and geography, spent twenty years in the area known as the Pimeria Alta, delineated on the east by the San Pedro River, the north by the Gila Valley and on the west by the Rio Colorado and the Gulf of California. Two of his major goals were to convert the Indians to christianity and to find a land passage to California to prove it was not an island. In 1700, Kino was again near the junction of the Colorado and Gila rivers. He ascended a hill in hopes of viewing the Gulf of California: "...but looking and sighting toward the south, the west, and the southwest, ...we saw more than thirty leagues of level country, without any sea, and the junction of the Rio Colorado with this Rio Grande..., and their many groves and plains." (Bolton 1919: 1, 249). In the flood plain in 1701, Kino wrote that the Indians: "...showed themselves most affectionate toward us, ...especially in opening for us some good, and straight and short roads through the thickets of the abundant and very dense woods, which were on these most fertile banks." (Bolton 1919: 1, 316).

Cottonwoods are first mentioned specifically by Father Sedelmayr in 1744 during his endeavors along the Colorado at the junction of the Bill Williams River: "The Indians burn the trunks of the alders [willows] and cottonwoods and when they fall they burn the tops of them until they have a pole of the size desired." (Dunne 1955: 31).

Thirty years later, in 1774, Fathers Diaz and Garces accompanied Captain Anza to the Colorado River. After they crossed the river near Yuma, Arizona, Diaz wrote: "On its banks there are many cottonwoods, most of them small." (Bolton 1930: 2, 264). The following day (9 February), Diaz wrote: "...we camped on the bank of this river below its junction with the Gila... Its banks and adjacent lands are very thickly grown with cottonwoods, which would serve for any kind of building." (Bolton 1930: 2, 267-268). On that same day, Captain Anza measured the Colorado River and commented on the plant communities: "...one can see clearly the junction of the rivers and the immense grove of cottonwoods, willows useful for thatching, and other trees, both upstream and down." (Bolton 1930: 2, 169).

Diaz and Anza journeyed westward to the coast, leaving Garces to continue his missionary work. In his travels north along the river in the vicinity of Ehrenberg, on 28 February 1774, he wrote: "...I arrived at eleven o'clock in the forenoon at the beaches and the groves of the Colorado, halting at a very long and narrow lagoon..." (Bolton 1930: 2, 379). As he traveled north above the Bill Williams River, he viewed the Chemehuevi Mountains and described the area now under the upper end of Lake Havasu: "In the vicinity of the sierra I saw much water, groves and large beaches, which must be those of the Colorado River." (Bolton 1930: 2, 385).

TRANSIENT PIONEERS

The crude Spanish Missions built on the lower river were destroyed in 1781, and most of the inhabitants, including Father Garces, were killed. Spanish activity in the area waned and between the late 1700's and 1850, only a few passing explorers, trappers and pioneers visited the lower Colorado River. One diary, that of Jose Joaquin Arrillaga, contained worthwhile vegetative descriptions where he approached the Colorado near its mouth and then traveled north to Yuma. On 19 September 1796 he wrote: "At half past three in the morning I took up my march to the east,...and at sunrise I was already in sight of the cottonwoods of the Rio Colorado." He crossed the Colorado River near Yuma and continued east: "After one leaves the banks of the river there is not a useful tree to be found, except the mezquite grove where I set out, and this serves for nothing but firewood," (Arrillaga 1796 MS).

A number of trappers were known to have illegally entered the now Mexican territory (Weber 1971) which included the region of the Colorado River. They were tight-lipped and

nly one, James Ohio Pattie, in 1827 left ecords of the Colorado River environment: The river, below its junction with the Helay, s from 2 to 300 yards wide, with high banks, hat have dilapidated by falling in. Its ourse is west, and its timber chiefly cotton-ood, which in the bottoms is lofty and thick et." (Pattie 1831: 129).

AMERICAN EXPLORERS

The best and most complete records of ottonwood distribution, abundance and size ccur from the late 1840's on when soldiers nd scientists began working in the area of he lower Colorado River either because of war r to conduct various surveys. The United tates boundaries were expanded to the Pacific cean in the 1840's and in 1846, the United tates went to war with Mexico for land acqui-ition, the Colorado River being part of this egion.

Lt. William H. Emory (1848: 99-100), opographical Engineer accompanying the "Army f the West" in 1846, recorded his observa-ions in the area of the Colorado-Gila junction: 'The banks are low, not more than four feet igh, and judging from indications, sometimes, hough not frequently, overflowed.... The growth in the river bottom is cotton wood, illow of different kinds,..."

A member of Emory's party, A. R. Johnson, also kept a journal and observed that: 'The Colorado disappears from here in a vast ottom; the last we can see of its cotton-woods is in the southwest." (Emory 1848: 609). The following day, after a 10 mile march, they again reached the river and Johnson stated: "...the river here is about ten miles wide, and much of the land could bear cultivation; it is all now overgrown with the most impene-trable thickets of willows, mesquite, Fremontia, etc." (Emory 1848: 609). The term "Fremontia" was frequently used to denote cottonwoods because the species was named in honor of the naturalist J. C. Fremont.

One of the many commissioners of the trouble-plagued boundary survey, John R. Bartlett, published his "Personal Narrative of Explorations" along the Colorado River in 1854. His following description of the Algodones area in 1852 is duplicated by a photograph (plate 1a) some 50 years later and then again in 1976 (plate 1b). In his description of the area (Bartlett 1854: 149-151) he wrote:

> June 9th, 1852 - Our journey was through a bottom filled with mezquit and cotton-woods; ...Our eyes were greeted with a sight of the great Colorado River, twelve miles below its junction with the Gila, at a place called "The Algodones," and soon after, we halted upon its bank. It was much swollen, and rushed by with great velocity, washing away the banks and carrying with it numberless snags and trees. The road ran along the river's bank, which, as well as the bottom-land, was filled with a dense forest of willows, cotton-woods, and mezquit.

Lt. Amiel Weeks Whipple (1856: 3(1), 109) in his exploration of a railroad route along the 35th parallel described the Chemehuevi Valley (79 years after Garces): "On both banks are strips of bottom lands, from half a mile to a mile wide. The soil is alluvial, and seems to contain less sand and more loam than is found in the valley of the Rio del Norte. But here, as there, are occasionally spots white with efflorescent salts. A coarse grass grows luxuriantly upon the bottoms. Bordering the river are cotton-woods, willows, and mezquites, or tornillas." Dr. J. M. Bigelow, surgeon and botanist in Whipple's party, described the same area: "From the mouth of Bill Williams' fork to the point above where we crossed the Rio Colorado, is about sixty miles.... Along the valley of this river, alamo [cottonwood], mezquite, and willow form the principal, and almost entire, kinds of trees." (Bigelow 1856: 4, 13).

The interest in river navigability was so strong in 1857 that a government expedition was organized. Lt. Joseph C. Ives, Corps of Topographical Engineers, was directed to determine how far and to what extent the Colorado River was available for steamer traffic. At Camps 50 and 53, Ives described Cottonwood Valley and Round Island. The latter was commonly called Cottonwood Island because of the heavy forest of large cottonwood trees. Of Cottonwood Valley, Ives (1861: 78) reported: "Groves of cottonwood trees, of a larger growth than any seen before, indicate that there is some alluvial land, but the valley does not appear to be of great extent.... The Cottonwood valley was found to be only five or six miles in length and completely hemmed in by wild-looking mountains. The belt of bottom land is narrow, and dotted with graceful clusters of stately cottonwood in full and brilliant leaf."

AMERICAN EXPANSION

Ives' steamer exploration up the river, and the demonstration that the river was navigable, generated an abundance of steamer travel and allowed shipment of goods to the mining industry. In 1862, placer gold was discovered midway between Fort Yuma and Mohave, and the



Plate 1a (1894). Looking southeast into Mexico at Mexican-American Boundary Monument 207. Maturing cottonwood community with trees 20 to 30 feet tall can be seen in the background following the cessation of the fuel wood industry for steam boats. A community of arrowweed occurs between the marker and the cottonwoods.



Plate 1b (1976). Looking southeast into Algodones, Mexico.

town of LaPaz was born (Renner 1974). Fuel for steamers was readily available in the form of cottonwood, willow and mesquite, the latter being less desirable because of its slow-burning properties. Large quantities of fuel were needed frequently and fuel stations were established at 25-mile intervals. The Indians, realizing that a profit could be made, cut and corded the wood, selling it at $2.50 a cord (Leavitt 1943).

The continuing search for gold revealed deposits near present-day Oatman and in El Dorado Canyon (Dunning and Peplow 1959; Casebier 1970). The expanding mining activities increased the military presence and businessmen soon realized the potential for development.

G. W. Gilmore, a member of the Colorado Steam Navigation Company, submitted a report on the availability of fuel along the river after having taken a trip on the steamer Esmeralda in 1866 in which he stated: "...bends of the river in the bottom lands, which, as below Fort Yuma, are covered with vegetation and timber; the trees of the varieties already named are suitable for fuel, and are of very rapid growth. It is found that upon new lands formed by the cuttings of the river cottonwood, willow, and mesquite trees will be produced in three years large enough to cut for fuel... Trees are quite abundant for most of the distance, and plenty of fuel to be had."

His statements about Cottonwood Island were as follows: "...about 10 miles long by an average of about three miles wide, is a fine, level island, fertile and covered with grass, and having considerable timber.... An immense quantity of this wood was upon the island, estimated at several thousand cords" (Browne 1869: 462-464).

The need for exploration was almost over and although further expeditions would be sent, they would be of a very different nature. In 1875 and 1876, Lt. Eric Bergland, under the direction of George Wheeler, leader of the United States Surveys West of the 100th Meridian, examined the Colorado River as a potential irrigation source. Describing the vegetation of the Colorado River, he stated: "A most pleasant sight... Cottonwood Island, with its majestic cottonwood trees and rich vegetation, afforded a pleasant relief to the eye.... Along the river there is a rich growth of trees, principally cottonwood, and here the fuel is obtained for the river steamers." (Bergland 1876: 330-333).

In 1877, Lt. A. G. Tassin authored a document entitled "Report on the Forestry, Elevation, Rainfall, and Drainage of the Colorado Valley together with an Apercue of Its Principal Inhabitants the Mahhaos [Mohave] Indians" compiled while he was stationed at Camp Mohave. Never published, the report remains in handwritten manuscript form, often undecipherable. In his discussion of the vegetation, Tassin (1877: 5-6) noted: "Finally along the margin of 'lagunas' the most substantial of the Colorado timber the willow and cottonwood. The largest of these in the entire course of the river, are in what is called 'Cottonwood Island' between Camp Mohave and the Grand Canyon where they have attained a size which may be styled majestic.... The cottonwood, mesquite and willow are the principal, if not the only fuel of the country, the first having a diameter varying from two to twenty inches." In a latter section of his report, Tassin (1877: 30) wrote: "Cottonwood island the sole bottom-land between the Grand Canyon and Camp Mohave, is, as denoted by its appellation, celebrated for its splendid cottonwood trees which here attain their full size. Its area varies between from four to six miles in length and from one to three-fourths of a mile in width.... In a few years, however, its beautiful trees will have disappeared, a large demand being made on them yearly for fuel for the use of the _____ Mormons."

The General Land Office, now known as the Bureau of Land Management, initiated the original township surveys or cadastral mapping along the river in 1855. Not all the land was surveyed during the same time period. Figure 1 shows a reconstruction of the general vegetative types below Blythe, California in 1879 derived by interpreting floral descriptions contained in original field notebooks and then transferring these to the original field plats. The field notes contain exact measurements from section corners to points where the vegetation or topography changed. At each change notes were taken on soil, vegetation and general character of the land. Once a section (1 square mile) was chained, the surveyors took random walks (giving specific localities) through the section and again took notes at various places on vegetation, etc. Insight into the maturity of the community was also indicated when tree diameter values at breast height were noted and when trees were used as section corners. Although these data are semi-quantitative and highly time consuming to obtain, they yield the earliest aerial view of plant community extent, abundance and placement along the lower river. They further support previous and subsequent written descriptions in the historical record.

By about 1890, the use of and need for steamboats had declined, as had the fuel supply. Some steamer traffic ran north of Yuma, but to insure adequate amounts of fuel, they had to travel into the delta area (Sykes 1937: 37). The decreased need for steamers was in part due

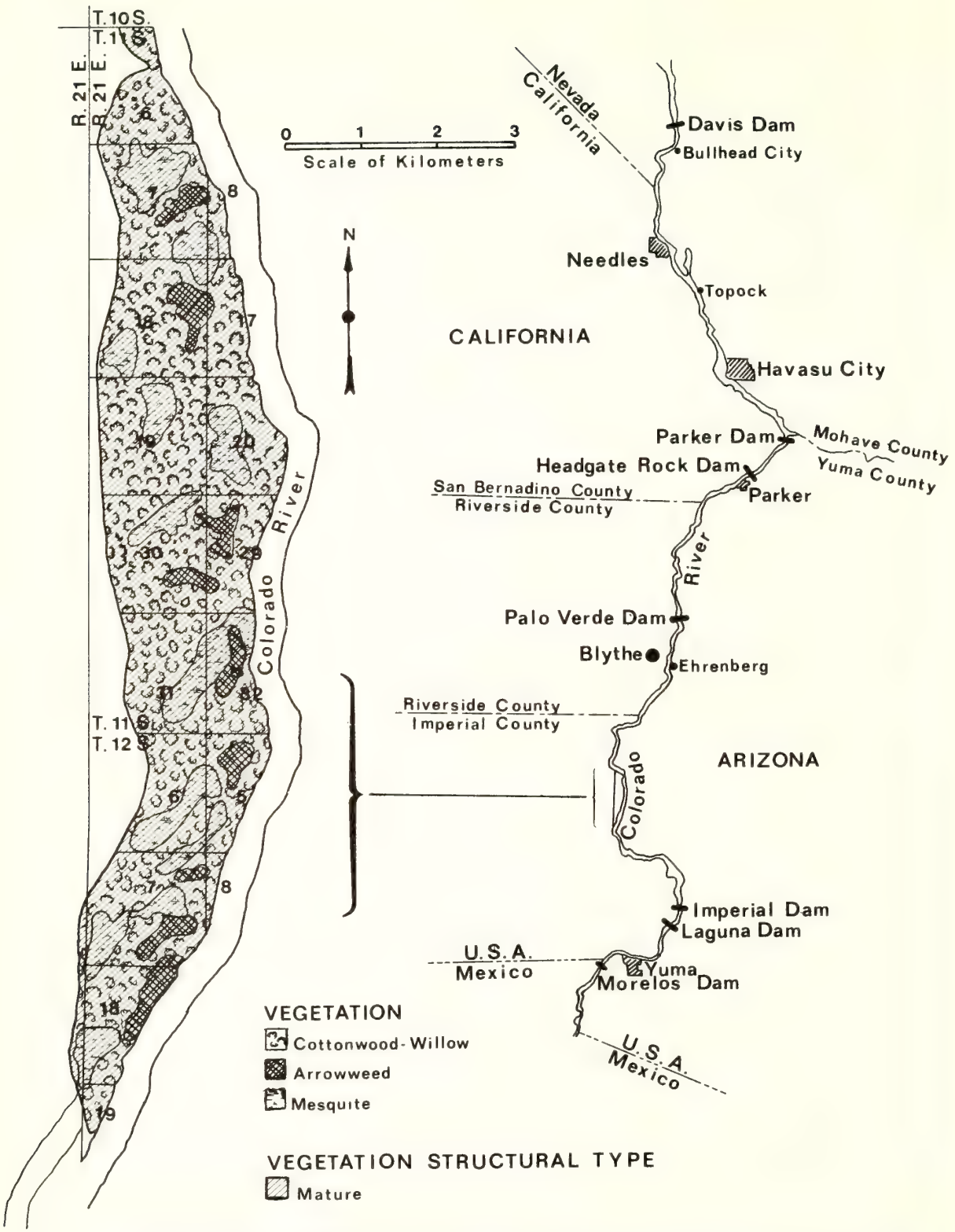


Figure 1.--Reconstruction of native plant community placement and species composition from original surveyor notes and plats along the lower Colorado River in 1879. Area surveyed by Benson.

to the completion of the railroad to Yuma (1877) and Needles, California (1883).

By the late 1800's, the importance of mining and other uses of the river had slowly declined and agriculture along the river was precarious because of the annual floods and constant shifting of the channel. In 1892 Imperial Valley was rediscovered by the Arizona and Sonora Land and Development Company. George Chaffey was instrumental in bringing water into the basin, and by 1904 the California Development Company claimed seven hundred miles of irrigation ditches and seventy-five thousand acres were under cultivation.

The winter of 1905 was one not to be forgotten. Unlike other years, the river began to rise in February and "the condition continued...until February of 1907" (Sykes 1937: 57). Despite attempts to control the flooding waters, by August 1905 the entire river was flowing into the intake of the Imperial Valley canal. Thus, the Salton Sink became the Salton Sea (Cory 1915; Tout 1931; Sykes 1937; Hundley 1973).

The flood of 1905 brought heavy public pressure for river management in the form of flood control and water storage. The Reclamation Act had been passed in 1902, the settlers were having continual problems with the development company, there were difficulties with the Mexican government, and the disastrous floods of 1905 and 1907 increased pressures to evict the promoters and have the Reclamation Service assume responsibility for the river. From about this period on, the Reclamation Service, now U. S. Bureau of Reclamation, played the most important role in developing the river as a utility, although lesser agencies such as the Imperial Irrigation District also played important parts.

One of the major roles in development was the installation of dams for flood control; the first, Laguna Dam, became operational in 1909. A flood in the fall of that same year "...was instrumental in completing the filling of the basin above Laguna Dam with detrital material within six months after the completion of the dam itself." (Sykes 1937:152). Floods continued and levees were raised until the big flood of 1922 which convinced people in Washington that larger dams were needed. In 1935 Hoover was operational. In 1943 Davis Dam, 1938 Parker Dam and Imperial Dam were completed. Lesser dams for water diversion also were constructed.

Concomitant with and following dam construction, engineers began to examine water movement rates, channel siltation and bank erosion. Many of these problems can best be solved by channelization, riprapping of banks and removal of sedimentation through dragline or dredge. All of these methods were employed to straighten and open channels to expedite flows. New and old eroding banks were fortified with riprap to increase bank stability.

Once the dangers of floods were reduced and flows were controlled by Hoover Dam, this allowed for agricultural expansion throughout the floodplain. Settlers claimed new lands and removed large and continuous tracts of natural vegetation for agricultural purposes. These activities, along with city and rural development, continue to claim numerous acreages once vegetated with natural communities. Much of this land, especially near the river, once supported cottonwood communities.

In the 1950's through the 1960's, two plans were formulated by the Bureau of Reclamation to remove riparian vegetation for the purpose of water salvage. Only one of these was ever implemented and this was in the Yuma flood plain area (Curtis W. Bowser, USBR, pers. com.). Van Hylckama (1970 and in press) has pointed out that water losses from a plant varies considerably during the year and past measurements have not taken this into consideration, possibly resulting in large errors.

In the late 1960's and early 1970's, a small flame of environmental concern was beginning to burn throughout the nation. In 1969 the National Environmental Policy Act was passed and federal agencies began to review policies and action decisions more closely. During this period the Regional Director of the Bureau of Reclamation, Mr. Edward A. Lundberg, established an environmental office headed by Mr. F. Phillip Sharpe. Efforts by these individuals in 1972 resulted in an extensive assessment of the little known flora and fauna of the lower river and a comprehensive and long-termed study was begun which was entitled "Vegetation Management for the Enhancement of Wildlife." These studies are still in progress and the legacy of environmental concern generated in the early 1970's is strongly supported by the current Regional Director, Mr. Manuel Lopez, Jr.

DISCUSSION

How extensive was the cottonwood community in historical times? As we swim through a sea of qualitative data, there is little quantitative information available to help answer this question. We know from historical records that cottonwoods were primarily restricted to the river's edge where seedlings became established in newly deposited soils. The following is an attempt to give some quantification to the

extent of cottonwood communities in historical times. If we assume that cottonwoods were absent in areas where the river cuts through canyons and thus remove 75 miles of the 275 miles of river between Davis Dam and the Mexican boundary, this leaves approximately 200 miles of potentially suitable habitat for cottonwoods. If the mean width of the cottonwood community along the river was 100 feet on each side of the river, we can compute a minimum area of 5,000 acres of cottonwood habitat. This figure is conservative, but it yields a value which will be instructive in later discussion.

The Indians exerted some influence on the ecology of the cottonwood community, especially by using fire to fall and size timbers. Cottonwoods cannot tolerate much heat and do not resprout from the roots following a hot fire. But to expedite discussion, in this report we will assume the Indians' influence on the cottonwood community along the river was minimal and capricious.

The influence of the Spaniards on the cottonwood community appears more minimal than that of the Indians except for the introduction of livestock in the early 1700's (Forbes 1965). Spanish activity was concentrated primarily around the Yuma area. The spread and extent of use of domestic livestock by the Indians is not well known, but Forbes (1965:287) reported from hearsay evidence in 1842 that the Quechan and Mohave Indians "...own large numbers of horses and cattle..." Not all the Indians owned or had access to livestock or Browne (1864) would not have observed them starving and eating rodents and reptiles. The primary damage of livestock to cottonwood communities would have been to seedling or sapling stands which would have been important foraging areas for domestic livestock. More mature communities were sometimes cut if livestock forage was scarce; Pattie (1905:188), for example, stated, "Our horses also fared well, for we cut plenty of cotton-wood trees, the bark of which serves them for food nearly as well as corn."

The first and most widespread reduction of cottonwood communities appears to have taken place during the period of steamboat use on the lower river (1855 to 1890). Cottonwoods and willows, fast burning woods, were located nearest to the river and were one of the primary fuels for powering the vessels. The extent of reduction of the cottonwood community is supported by Tassin (1877:30) who predicted the denuding of cottonwoods from Cottonwood Island, which came to pass. Another indication of the reduction of maturing cottonwood communities is exemplified by the necessity for steamers planning long trips up river from Yuma to go into the delta for wood to insure an adequate fuel supply (Sykes 1937). As fuel demands abated in the late 1880's, cottonwood communities began returning; and the photograph (plate 1a) taken in April 1894 by Mearns shows redeveloping cottonwood communities at the Mexican-United States boundary.

The floods which occurred during the years of 1905 and 1907 were of a greater magnitude and longer duration than any described in historical accounts. The destruction and removal of natural communities must have been far greater and more widespread than the 1852 flood which washed away banks and carried in its waters "numberless snags and trees" (Bartlett 1854:50). Presumably, the newly deposited and moist soils again would have provided the basic habitat for cottonwood seed germination and the repetitious reforestation process. Accounts by Grinnell (1914) in 1910 indicate that the cottonwood communities were returning and the 1945 photograph (plate 2a) provides pictorial testimony. Aerial photographs taken every three to five years, beginning in 1942, show that the majority of the trees were gone by 1967 and plate 2b, taken in 1976, revealed only four or five isolated trees in the bottom right. Dense stands of salt cedar presently cover areas previously supporting cottonwoods.

Salt cedar was introduced in the New World in the early 1800's both as a soil stabilizer and as an ornamental (Horton these proceedings). Its entry to the lower Colorado River must have been sometime after 1910 when Grinnell (1914) made extensive museum collections of plants and animals. He makes no mention of it in his publication or field notes, and had it been at all common, he would have found and collected it. The species appears to have become established between 1910 and 1920 and began to spread rapidly in the 1930's and 1940's. By the 1940's it dominated large areas along the Gila (Marks 1950; Haase 1972; Turner 1974) and Colorado (Robinson 1965) rivers.

Horton (these proceedings) discusses the biology of salt cedar but a brief discussion is necessary to gain insight into the events that transpired between 1945 and 1976. The species produces seeds over a long period of time and seeds are both wind and water disseminated. They germinate vigorously in newly deposited alluvial soils. The species is deciduous and when in relatively dense stands (periphery of adjacent trees touching), the annual litter accumulation after 10 to 12 years produces a highly flammable condition. The above ground portions are killed following a fire, but suckers from the root stock reappear in one to two weeks, the burn cycle repeats itself every 10 to 20 years (Anderson and Ohmart MS).



Plate 2a (1945). Aerial oblique looking west into California about 25 miles north of Blythe. The river is flowing in the foreground to the right and then to the left. In bottom right, cottonwoods can be seen along the old braided stream channels on the cut bank. Understory is primarily sparse arrowweed with taller willows or salt cedar near the cottonwoods. The peninsula supports many cottonwoods, willows and arrowweed.



Plate 2b (1976). The camera station is higher and closer than in the previous photograph. Dense salt cedar and arrowweed have invaded the areas previously occupied by cottonwoods. Isolated cottonwoods persist in the lower right. On site remnant blackened tree stumps are persistent testimonials of past fires. Mesquites have become established along the peninsula on the higher and better drained soils.

Cottonwood communities were in the process of returning following the floods; but when salt cedar began invading the lower river, it must have started mixing with the maturing cottonwoods. The proximal location of the cottonwood communities to the river and on soils only inches above the water table provided the type of habitat that salt cedar does best on and aggressively spreads over. Some individual cottonwoods were probably removed for firewood by man and for food by beavers. Today remaining cottonwoods occur as isolated trees or as irregular rows with little understory, mixed with sparse willow communities, in pure stands or temporarily mixed with salt cedar. The latter being temporary as exemplified by the area around Hunters Hole in the Limitrophe Division which burned two years ago and killed all the mature cottonwoods. Many of the remaining cottonwoods along the lower river are mixed with sparse willows and these willows may have served as a buffer which prevented or slowed the invasion of salt cedar by shading out seedlings. Anderson and Ohmart (MS), in studying rodent succession in fire altered salt cedar communities along the lower river, have only found two salt cedar communities of 50 acres or more that have survived fire for more than 20 years.

Many cottonwood communities have been lost to expanding agriculture channelization projects, inundation of lakes behind dams and possibly the placement of dredge spoil materials. Agriculture only poses a minor threat to remaining cottonwood communities since there are only so few left, and they occur primarily on lands between the levees which are not farmed. River management activities tempered by environmental concern, require an Environmental Impact Statement and mitigation for project losses.

The demise of cottonwoods on the lower Colorado River has been related to implementation of dams, and the data indicates that dams expedited the natural loss by stopping annual overflow. This periodic flooding and water movement through the communities covered or washed away litter accumulations. Litter covered with sediment during overflow rapidly decomposed to release nutrients and add humus to the soil. River management stopped these natural overflows and allowed litter accumulation which in turn has resulted in the increased frequency of communities being burned. This has led to the loss of many cottonwood communities from fire.

Cessation of annual overflows and natural channel movements also curtailed the formation of the basic cottonwood seedling habitat, bare sandy soils with high water tables, which appears essential for cottonwood seed germination. The rapid spread of salt cedar and slow demise of cottonwoods began about the time major dams were implemented, the mid 1930's. It is somewhat of a moot point whether major dams tipped the ecological balance to favor dominance of salt cedar over cottonwoods or if cottonwoods could have retained their dominance over the invading salt cedar on the lower Colorado River. Currently the success of cottonwood regeneration has not been stopped, but it has been lowered to the point where it is negligible. Campbell and Dick-Peddie (1964) reported that cottonwoods could maintain their dominance over salt cedar in natural conditions on the upper Rio Grande in New Mexico, but it is doubtful this would be valid along the lower Colorado River. Even without dams it appears highly unlikely that cottonwood communities could have maintained their dominance along the lower Colorado River over the aggressive and fire adapted salt cedar.

This conclusion is supported by examining the loss and persistence of cottonwoods in natural communities along other southwestern streams. A reach of the Gila River in Arizona between Kearny and Florence is still intermittently flooded but contains few lone cottonwoods and no gallery forest. Conversely, the Verde River in Arizona above and below the dams possesses good cottonwood gallery forest and salt cedar appears to be having more difficulty invading this riparian system than it has had on the Salt or Gila rivers. Another factor appears to be important--total dissolved solids (TDS). Further support of the importance of TDS is indicated by the return of native vegetation along the Salt River below the Flushing Meadows sewage treatment plant in west Phoenix, Arizona. In this area, salty native ground water is being displaced by secondary sewage water and following the flood conditions in the 1960's which scoured away much of the salt cedar in that area, native communities are rapidly returning. It is highly improbable that these native communities would have returned in competition with salt cedar if salt cedar removal by flood waters was the only cause. Many areas have been cleared of salt cedar only to have it promptly return. Observations along the Rio Grande in New Mexico and Texas further support the importance of low TDS and cottonwood dominance over salt cedar. Along the upper portion, around Albuquerque, New Mexico, cottonwoods appear to be thriving and maintaining their dominance. But between Las Cruces, New Mexico, and El Paso, Texas, the frequency of extensive gallery forests declines and individual trees show heavy plant parasite infestations; to the extent that they are dying. Further down river in Texas between Presidio and Fort Quitman there are no gallery forests remaining; only lone cottonwoods remain isolated along ditches or canals from the tall and dense salt cedar

forests. All along the river from Albuquerque to El Paso extensive agricultural and industrial effluent enters the river to slowly work its way down stream. Salts from these and natural sources can be seen covering many acres between Fort Quitman and Presidio following the subsidence of sluggish and intermittent winter floods. Dams have stopped the once rapid moving floods which once flushed and leached salts into the gulf, leaving rejuvenated soils.

Other factors, both man caused and natural, may or may not be involved in each case and should be examined in depth before reaching a final conclusion as to the reasons for cottonwood disappearances. We know that domestic livestock concentrate in riparian communities and heavily utilize young cottonwoods, but we know nothing about possible climatic changes and their effects postulated by Hastings and Turner (1965). What effects have these changes had on cottonwood communities, if their thesis is correct? Much remains to be learned about the ecology of riparian communities and unfortunately there is little information available on the natural history of most of these plant species.

Cottonwood communities have declined from high abundance (5,000 acres plus) along the lower Colorado River in the 1600's to scattered groves containing a few mature individuals today. Anderson and Ohmart (1976) have estimated that only 2,800 acres of cottonwood-willow community remain along the lower river. If one was to consider pure cottonwood communities, it would be less than 500 acres.

In conjunction with the loss of the cottonwood resource, we must have experienced population reductions in bird species which show a strong preference for cottonwood habitats. Summer Tanagers (Piranga rubra), Yellow-billed Cuckoos (Coccyzus americanus), Wied Crested Flycatchers (Myiarchus tyrannulus), Brown Creepers (Certhia familiaris), and many small insectivorous birds (mostly warblers) breed or winter in these habitats. Numbers of some of these species are very low (Anderson and Ohmart 1975) and for all practical purposes some species would be extirpated from the lower river if cottonwood communities were eliminated.

Can anything be done and is anything being done to prevent the further loss of this resource? The U.S. Fish and Wildlife Service has recently bought the remaining cottonwood gallery forest that was not previously part of the Havasu Wildlife Refuge on the Bill Williams River and incorporated it into the refuge. Although adjacent to the Colorado, along the lower end of the Bill Williams River, there is a young gallery forest of about 700-800 acres. If this area is properly managed and prevented from burning, it should survive. Willow Valley Estates, a private housing development in the Mohave Valley was designed with open space areas and has planted natural vegetation (especially native cottonwoods). It is a small area, but some of the habitat specific bird species are found in this community. Recently, the Bureau of Reclamation has begun experimenting with the redevelopment of cottonwood-willow communities for operational enhancement and mitigational measures. Currently 25 acres of dredge spoil in the Cibola Division are being revegetated with cuttings or seedlings of native cottonwoods, willows and honey mesquite, the results look promising. A smaller area below Parker Dam also is being revegetated with cottonwoods and the young trees are doing well.

A look at the past allows us to examine changes and postulate causes. Hopefully we can then turn to the future, with the knowledge of the past, and formulate management plans so we can ultimately move with dispatch to manage and expand the availability of a valuable resource that is rapidly disappearing. To insure the preservation and perpetuation of this resource, all responsible agencies must make special efforts to preserve what cottonwood communities remain on their public trust lands and even attempt to reestablish new communities through transplants of native stock. It is expensive and requires a lot of manpower and attention but if this biotic community is to be preserved for future generations the effort must be undertaken soon.

ACKNOWLEDGEMENTS

We wish to thank Linda Cheney and Linda Cross for their help in preparing the figure, John Saunders for his help in transfering surveyors' notes to plats, Eugene E. Hertzog for duplicating the 1976 photographs and Penny Dunlop and Katherine Hildebrandt for their help in typing revised copies of the manuscript. B. W. Anderson and W. A. Dick-Peddie kindly reviewed the manuscript and made helpful suggestions. Final thanks go to Jane Durham whose patience preparing the literature cited section and scrutinizing help in later copies were invaluable. We deeply thank these people.

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Session II

Discussion Leader: Robert Jantzen
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Wildlife Conflicts in Riparian Management: Grazing[1]

Charles R. Ames[2]

Abstract.--Grazing has a negative impact on riparian zones. These zones constitute a small but critically important part of the range resource.

The riparian types in southern Arizona have increased from what they were 100 years ago. The increase has occurred through stream eutrophication and is most noticeable where the streams pass through the grassland type.

Protection of the riparian type where grazing is an established use can only be effectively achieved through fencing.

Wildlife managers frequently express their concerns about the impact of grazing in the riparian zones and justifiably so. We have all seen examples of riparian types where there is virtually no reproduction or mixed age classes of the trees or shrubs. The type is dominated by mature and overmature trees. Trees growing in riparian sites are usually relatively short-lived. It is entirely possible for a riparian zone to completely disappear within a span of a man's lifetime where grazing use is prevalent.

Cattle exhibit a strong preference for the riparian zones for a number of reasons. Cattle prefer the quality and variety of forage available. Riparian forage is higher in palatability because it has more moisture in it whether it be shrubs, forbs, or grass. Moisture content, probably more than any other factor, influences palatability. A preferred species of forage growing on a dry hillside will not be nearly as palatable as the same species growing in a riparian zone.

Availability of water in most riparian areas provides a strong influence for livestock to frequent the area.

If the surrounding country is rough and rocky, livestock tend to concentrate along the riparian areas just to give their feet a rest. In hot climates, livestock seek the shade available along the riparian areas. In cold climates, they seek shelter from the cold winds.

If livestock are left to their own preference the riparian zones get continued yearlong use with no respite from grazing. These critical zones represent a small but important percentage of the total range area. This is where the nongame birds and animals congregate unless it is totally devastated.

On the Coronado National Forest, approximimately 20% of the grazing allotments have significant riparian zones. Southern Arizona perhaps is unique in that we probably have more riparian zones today than there were 100 years ago. The increase has been due to overgrazing during the 1890's and early 1900's.



Figure 1.--Monument No. 98 on Mexican border. Located on west bank of San Pedro River. Photo taken 1892. Drainage virtually devoid of any riparian growth . San Pedro River was perennial stream with fish, frogs and turtles.

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[1] Paper presented at the Importance, Preservation and Management of the Riparian Habitat Symposium, Tucson, Arizona, July 9, 1977.

[2] Charles R. Ames is the Range and Wildlife Staff Officer of the Coronado National Forest, Tucson, Arizona.



Figure 2.--1969 photo showing dense growth of mesquite. Entire San Pedro River has dense growth of mesquite and other riparian growth.

During this period, there was a continual buildup of cattle to a peak number of 173,000 head by 1900 in the area now encompassing Pima and Santa Cruz Counties. Needless to say, the country was devastated. During the rainy seasons, the runoff resulted in serious flooding causing gullying and heavy soil loss.



Figure 3.--Monument 111 where Santa Cruz River leaves U. S. No riparian growth showing along stream bank. Photo taken 1892.



Figure 4.--1969 photo shows heavy riparian growt along water course.

Prior to this period, the San Pedro and Santa Cruz Rivers were perennial streams inhabited by fish, frogs, and turtles.

The resulting accumulation of silt in the stream with the soil nutrients provided the seed bed for the riparian growth now so prevalent along these streams. This process is called eutrophication.

A recent example of this is along the Santa Cruz River where the Nogales Highway was washed out in the 1967 flood. This occurred about 20 miles north of Nogales. The resulting silt bed formed in the bend of the river produced a dense stand of cottonwood trees now 30 to 40 feet high

The riparian types in the mountain areas of the Coronado have probably remained fairly stable with little change through the years. The increase of this type has occurred by extension through the grassland type by the stream eutrophication process.

In general, it would seem we can conclude that riparian types undergo change. They recede in some areas and increase in others.

It is a well established fact that we are in trouble trying to retain riparian zones in a reproductive condition. The question arises - what can we do about it?

First of all, I believe we need to do an intensive classification job on our riparian types. These would logically fall in two categories: threatened and unthreatened. Of those

in the threatened category, select the key areas. These would be the zones determined to be essential to keep. They may be critical habitat for rare and endangered species. Therefore, reproduction of the tree and shrub species must be ensured.



Figure 5.--photo of Monument 118 where Santa Cruz River comes back into U.S. Note limited scattered growth along water course.



Figure 6.--1969 photo shows a veritable jungle of heavy riparian growth. Original masonry monument washed out in flood in 1914 and replaced with steel monument in 1917.

It has been our experience on the Coronado Forest, that there is no known system of livestock management that will give adequate protection to a riparian zone. Even short term use or seasonal use is inadequate. Because these areas are usually extremely narrow and linear in character, grazing for only a few days can seriously impair its reproductive capability. It's like having the milk cow get in the garden for one night.

The only way we have been able to ensure adequate protection of our riparian types is by fencing them out from livestock use. This, of course, is coordinated with the livestock management plan to provide for watering places and logical pasture divisions.

We have initiated a riparian fencing program of our key drainages with excellent results. One in Parker Canyon has been fenced for nearly 2 years. The response here has really been encouraging. We have another currently in progress of being fenced which we hope will be equally productive.

Wildlife Conflicts in Riparian Management: Water[1]

Charles E. Kennedy[2]

INTRODUCTION

This paper is a summary of observations of the need for a better understanding of the interactions of stream-riparian-vegetation-energy-nutrients-water production-aquatic life and terrestrial life. Most of the riparian ecosystem interactions have had very little attention in Arizona and New Mexico.

WHAT IS WATER

In its pure form water is a colorless, clear liquid compound of hydrogen and oxygen. Water in the riparian zone is never just H_2O. It is a building block for photosynthesis by riparian and aquatic vegetation. It carries assorted dissolved salts (many of which are nutrients). Water carries dissolved organic matter, fine and coarse particulate organic matter, and supports numerous aquatic life forms, vertebrate and invertebrate, large and small (fish plankton, bacteria, etc.) Water, through the riparian vegetation, supports a wide assortment of interesting and valuable terrestrial wildlife species. Water is an energy source in itself as it forms natural, meandering channels and transports particles, large and small.

ENERGY-RIPARIAN ECOSYSTEM

A number of studies have shown that fish production is much lower where grazing occurs in the riparian zone. For example, in the Rock Creek Floodplain Investigation (Marcuson 1970) there were 63 pounds per acre of brown trout in the heavily grazed area as compared to 213 pounds per acre in the ungrazed area.

Bob Phillips (USFS) and others demonstrated the presence of 31 steelhead in a 100-foot heavily grazed section and 75 steelhead present in a nearby lightly grazed section (personal communication).

(Fisher 1970) demonstrated that 99% of the annual energy budget for Bear Brook comes from the surrounding forested watershed or from upstream areas. Even in large streams, such as the Missouri River, fifty-four percent of the organic matter ingested by fish is of terrestrial origin (Berner 1951).

(Cummins 1974) diagrammed the fate of heterotrophic stream organic materials (dissolved and particulate) and showed a conceptual model of stream ecosystem structure and function.

(Ensign 1957) found that in Mt. Vernon Creek, southern Wisconsin, where cattle were free to graze the streambanks, terrestrial insects made up only 4% of the annual food of brown trout. In Black Earth Creek (a few kilometers from Mt. Vernon Creek) where streambanks were protected from grazing, terrestrial insects comprised 15% of the annual diet of brown trout.

Thus, we find in the literature that streams are often energy dependent upon the riparian vegetation and the watershed. (Likens and Bormann 1974) have demonstrated the nutrient linkages between streams and watersheds. They state clearly that the key to wise management of aquatic ecosystems is wise management of the watershed.

We can extrapolate these works and assume that many streams in Arizona and New Mexico will also be dependent upon the riparian zone and their associated watersheds for their primary energy sources. But in this area, we have streams which can begin at elevations up to 11,000 feet on Mt. Baldy on the Apache National Forest (where they are comparable to streams in Northern United States or Canada) descend to intermediate elevation where they support warm water species comparable to southern and Midwestern United States streams. Others, purely desert streams, are unique in the United States. Just as Arizona and New Mexico are rich in the number of wildlife species produced in the wide diversity of habitats, Arizona and New Mexico streams are also rich in diversity running the gamet from high altitude, cold, clear, mountain streams, through warm, algae rich mid-elevation reaches, finally to low elevation pure desert reaches. For

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[1]Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

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instance, we have grayling, an arctic fish, in a lake above the Mogollon River; while only 50 miles away there are channel catfish, a warm water species, in the Verde River.

Energy interdependence will follow a similar gradation. The high streams are most likely to be dependent on outside sources of energy for the aquatic organism food base. The mid-elevation streams may have somewhat more ability to capture energy in the stream through algae, diatoms, and rooted vegetation. The low desert streams with riparian vegetation and with tributaries supporting riparian vegetation may fix substantial energies in the aquatic environment, but will also receive substantial inflows of plant detritus during storm flows. (Burns 1977)

We need to develop a stream classification system which incorporates these energy sources as a significant criteria, and we need to study stream energy budgets on typical reaches of several stream types, i.e. cold water, intermediate, and warm water to document the stream-energy system sources and gradations of dependence upon terrestrial sources.

No doubt we will find streams which are largely dependent upon the riparian vegetation for a substantial portion of their organic-energy and partially dependent upon the watershed for dissolved organic matter.

As I said earlier, fish weigh less and are less abundant in grazed portions of streams. Putting this fact with the dependence upon energy from the riparian zone, we can understand that plant material eaten by cattle in the streamside strip will not be available for food for aquatic organisms in the stream. Fish will have less food. I used the term "streamside strip" here because on many miles of our streams in the southwest free choice grazing by cattle has brought about complete type conversions in those immediate areas alongside streams.

After many years (50 to 100 or more) of grazing in this "most palatable area" the old riparian trees have died, seedlings are eaten and killed until only the most "grazing resistent" unpalatable grasses and/or trees remain. This type conversion at higher altitude has eliminated alders and willows, leaving only associated grasses. In the middle elevations the sycamore cottonwood and others are often entirely missing to be replaced by bermuda grass-desert willow-seep willow and at some elevations, tamarisk. Thus, grazing is a significant force in altering streamside composition - just as it is throughout the watersheds.

Actual streamside composition varies from those areas where all of the natural species are gone with no seed sources remaining, to other streams that have a few decadent widely scattered specimens with most species present. Fencing alone will start the stream toward recovery, but plantings of seedlings will be needed on many.

In figure 1 we see only a few remnants of willow and narrowleaf cottonwood. The stream is appropriately called the Rio de las Vacas and is on the Cuba District of the Santa Fe National Forest, at elevations from 7000 to 9000 feet. The loss of shade for the stream, the loss of bird habitat and the premption by cattle of often the only source of green feed is obvious. The loss of energy to the stream is not so obvious. In fact, all too many times little thought has been directed towards learning how energy used by the stream flows through the ecosystem.



Figure 1

STREAM MORPHOLOGY

Another, more subtle, impact on the fishery occurs when riparian trees are eliminated by continual grazing. The stream is less confined to its banks and will have a more constant sediment load, especially from unvegetated stream banks. Overgrazing in associated watersheds creates higher peak storm flows. Overgrazing combined with hydraulic force of these peak storm flows plus the grazing by cattle on young seedlings keeps many streams in a young, undeveloped and raw condition.

Region 3 of the Forest Service (Arizona and New Mexico) has in National Forest streams approximately 4000 fish habitat improvement structures to make more pools in the miles and miles of flat, shallow streams.

An alternative to these structures and their maintenance is to fence cattle out of the narrow riparian zone so that the streams can progress through successional stages toward more stable conditions. As vegetation and trees become established in the immediate water edge area, the stream will, over time, become more narrow and deeper provided the associated watershed is properly grazed. Grazing levels must provide for suitable vegetative cover to insure soil protection and retard rapid runoff. The number of pools and their suitability for fish habitat will improve. Figures 2 and 3 show an area along a one mile reach of the Rio de las Vacas that has cattle fenced out. Stream profiles, photos, etc., are being established to document changes in stream morphology and riparian composition. Water temperatures in June 1977 reached 70°F. in this area. Narrowleaf cottonwood (Populus angustifolia), Arizona alder (Alnus oblongifolia) and willow (several species) comprise the bulk of the remaining riparian tree species. There are only about 50 individual specimens of narrowleaf cottonwood remaining in eight miles of the stream.



Figure 2

Figure 3 shows the remnants of an old trash catcher type stream improvement structure, entering the water at the arrow. Stones, silt, etc., caught by the fence posts and wire have somewhat constricted the stream making a slightly deeper spot just to the left of the fence. How much better for the fishery, the bird life, the esthetics, and the cattle if the dead trees had survived and reproduced until the roots provided cover, formed a pool and dropped leaves and insects into the stream.



Figure 3

(White and Brynildson 1967) have documented successional stages with drawings which clearly demonstrate the process (see figure 4). Time in these changes will no doubt be faster in Arizona and New Mexico at low elevations with long growing seasons and perhaps slower on the Rio de las Vacas at 8500 feet with a short growing season.

A great deal of research has gone into ways to produce more water on National Forests in Arizona. Much has been written about the evapotranspiration of water by riparian species, native and introduced. There have been no concentrated, integrated efforts to determine which mixture of riparian species might best serve the needs of all resources, the fishery, the bird and wildlife resource, esthetic needs and water production.

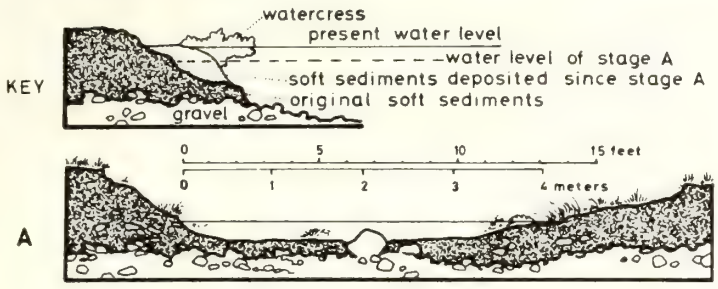
As manipulations are applied to watersheds (chapparal and timber) to produce more water, it will become more important to manage the riparian zone (which in one aspect becomes a water "pipeline") to insure all the intrinsic values while producing the maximum amounts of high quality water for downstream users. It is certain that a vigorous stand of well established riparian trees will produce the amenities we are interested in.

There may be ways to improve tree composition to favor energy flows for the fishery, reduce evapotranspiration for water production, and provide habitat for the bird life and other animal needs for green forage and cover. Perhaps leaves from Arizona walnut transpire less water and are better food for aquatic insects. Maybe the leaves have a higher calorie count - a better mix of nutrients.

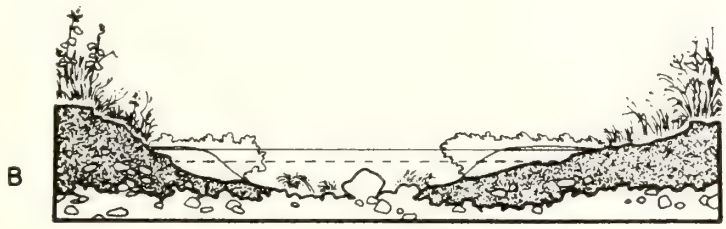
Some stages in natural development of a fertile lowland Wisconsin trout stream from overgrazed (A) to very productive (D-E-F) to overforested (G&H) when protected from grazing. A hypothetical 14-foot wide cross-section plus adjacent bank shown.

The complete sequence from stage A to stage E-F has been observed on Black Earth and Mt. Vernon Creeks near Madison.

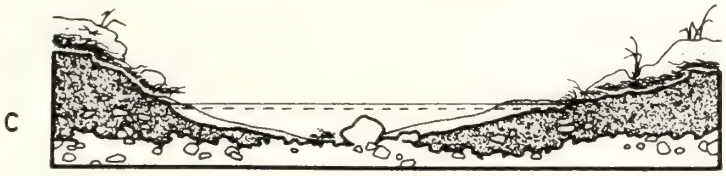
Later succession — stages G and H with many intermediates — is to be seen on other streams. Details of this succession vary from stream to stream, especially after stage E-F, but the passage from predominantly herbaceous to predominantly woody vegetation generally has the same detrimental effects. Good management for trout — and other wildlife — would be control of vegetation to maintain stages D-E-F.



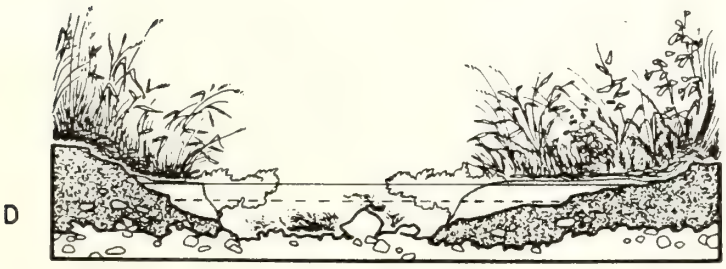
MIDSUMMER CONDITIONS UNDER HEAVY GRAZING BY LIVESTOCK: Bank vegetation and watercress grazed and trampled. Banks eroding, and stream bed mostly covered by shifting silts. Submergent plants grow poorly. Whole surface of water and stream bed exposed to sun. Greatest depth in cross-section only 9 inches (22 cm). These conditions offer trout no shelter, no place to spawn, little food, and frequently unfavorable temperatures.



MIDSUMMER CONDITION AFTER 2 TO 4 YEARS OF PROTECTION AGAINST GRAZING: Bank vegetation forming a turf. Abundant watercress at edges of stream constricts channel, thus deepening and speeding water. Soft sediments scoured from much of stream bed and trapped in cress beds. Submergent plants thriving. Only about half the former stream width exposed to sun. Greatest depth about 20 inches (50 cm). Trout have ample shelter beneath watercress, beside rock, and among submergent plants. Firm stream bed and many plants provide substrate for many animals that trout eat. Newly exposed gravel is a place to spawn.



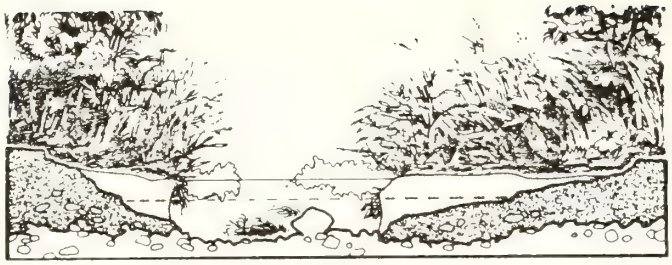
LATE IN THE NEXT WINTER: Watercress has withered and drifted away. The silts it held slump into the channel, smothering many of the trout eggs buried in gravel and preventing fry from emerging into stream. Food is scarce. Broad surface of water exposed to cold. Shelter for trout almost as poor as at stage A and will not redevelop until May or June.



MIDSUMMER CONDITION IN ABOUT 3RD TO 5TH YEAR AFTER GRAZING HALTED: Further scouring of fine sediments from stream bed. Silt bars at stream edges being tied down by reed canary grass with its tough system of roots and runners. Watercress flourishing, and submergents at peak of development. Only 4 feet of stream width exposed to sky, and this shaded much of day by high grasses. Greatest depth in cross-section about 2 feet (60 cm). For trout, shelter, food, and spawning gravels are ample.

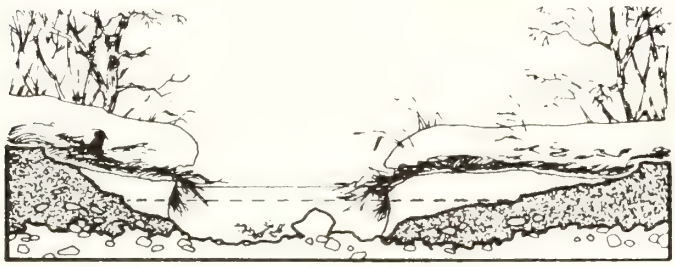
Figure 4

E



MIDSUMMER A FEW YEARS LATER:
Silt bars further stabilized by turf. Channel narrowed by 40% to 50% since stage A. Only 2 feet of stream width exposed; therefore submergents less abundant. Also less volume of watercress due to shade of taller plants. Woody vegetation starting to dominate.

F



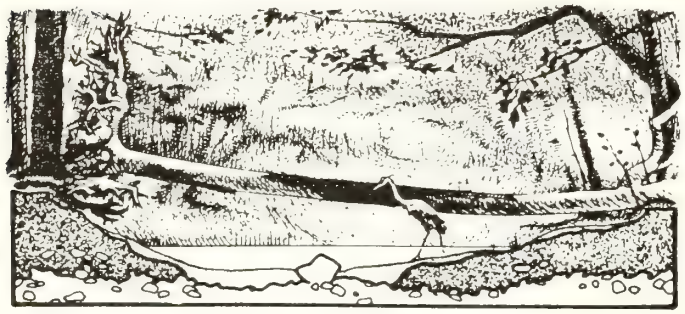
LATE WINTER DURING STAGES D AND E:
Turf still holds bank materials firmly. Overhanging fringes of matted grass provide shelter for trout. Gravels remain clean enough to allow normal hatching and emergence of fry.

G



MIDSUMMER 10 TO 20 YEARS LATER:
Alders or other high bushes predominate (saplings of ash, elm or maple at left). Turf completely shaded out. Water level high due to clogging by debris. For trout, food may be scarce, shelter is excellent beneath banks, among roots and fallen branches.
But:
Innermost rows of alders will soon tip into channel, further clogging flow and destroying overhanging bank. The largely vegetational processes of bank-building will not be repeated as long as shade persists.

H



MANY YEARS LATER:
Mature forest . . . Dense shade. Few plants on forest floor. Banks have eroded, channel has spread and silts again cover stream bed. Channel less than 1 foot deep. Little shelter for trout. Even trees undermined by current and toppled across the stream may provide poor hiding cover. Conditions almost as bad as in stage A.

Figure 4

This example reminds us that there are hundreds of plants which regularly grow in the riparian. We know very little about their intrinsic values and how they interact in a normal, managed (not overgrazed) riparian ecosystem. Certainly a shaded stream with a nearly closed canopy over a narrow, deep stream will produce cool, clear, water and less sediment will reach the reservoirs, extending their lifetime. The fate of many species such as the bald eagle may ultimately depend upon the subtle energy flows needed to produce the fish which the eagles are dependent upon. The fate of several fish like the endangered squawfish and others are also dependent upon a properly functioning riparian ecosystem.

This managed "riparian pipeline ecosystem" will hopefully produce ample quality waters for other downstream uses. The evapotranspiration in the pipeline is not wasted, society needs the products produced.

J. Stokley Ligon wrote 50 years ago, "Cold water fish and fishing streams are as seriously affected by overgrazed watersheds as is game. Not only do the extremes of low and high water, caused by floods and erosion, affect the normal flow and temperature of waters, but the destruction of willows, alders, weeds and grasses eliminates both food and shelter for cold water fish. No experienced angler fishes in sun-exposed streams where the water spreads shallow in unprotected flood-ravished watercourses; he seeks the cool shadows where the alders, willows or conifers overhang the banks, where the stream is narrow and banks with matted roots are secure along New Mexico's cold water streams today. Abuse by overgrazing of watersheds and watercourses, as no other cause, has deteriorated New Mexico's fishing."

The creation or perpetuation of the little winding stream jungles everywhere are a national as well as a state need. The space they occupy, whether on the farm, deep in the creek bottom, canyon course or on overflow lands, has no appreciable value from the standpoint of agriculture or stock raising, but as little jungles they have an intrinsic value. As boys how many of us got our greatest thrills and enjoyment from these little jungles - the jungles we resorted to at every opportunity to follow our dog aften rabbits, squirrels or coons, or to hunt quail, fish, or to set our traps for furbearers? The intensity of the job and satisfaction thus derived demands that this little institution, the wasteland jungle, be perpetuated for the American boy and man. These little spaces, properly protected, are the only means of conserving the small game in reclaimed canyons and valleys as commercialism agressively overrides every weakling of Nature that does not have the sympathetic support of organized forces to oppose it."

CONCLUSIONS

1. The fishery resource is often energy dependent upon the riparian vegetation and the watershed.

2. Uncontrolled grazing brings about complete type conversions in the riparian zone and prevents streams from progressing to more stable conditions.

3. Trees and other vegetation in the riparian zone control sediments, provide stream stability and tend to narrow and deepen channel morphology, which benefits the fishery resource.

4. Research is vitally needed to document and study the interactive and intrinsic value of the many plant species in the riparian ecosystem.

5. The fishery, wildlife, esthetic resources, and water quality and quantity are dependent upon these interactions and our efforts to integrate the needs of the various resources. Free choice, uncontrolled grazing is incompatible with these resources.

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Management Alternatives for the Riparian Habitat in the Southwest[1]

Gary A. Davis 2/

Abstract -- Exploitation, by man, has significantly altered the riparian habitat in the Southwest. For decades, the primary or dominant use of riparian habitat has been water management; other values were not considered. Management alternatives and objectives are evaluated for environmental consequences.

Diversity and numbers of plant and animal species are continually changing through geologic time. Disappearance of some plant and animal species and the emergence of others results from evolutionary processes of natural selection. Plant and animal species are constantly adapting to changing environmental pressures. Fossil records indicate that extinction is the inevitable fate of all species. Continual variation in the physical and biological environment initiate extinction in nature. When an individual species is unable to adapt to changing environmental stresses, it is replaced by others.

Prior to the appearance of Homo sapiens on this planet, extinction occurred as a consequence of natural phenomena. With the advent of humans, an additional stress was exerted on the physical environment. Some data imply that the rate of extinction increased as a result of human stress (Martin, 1967). Human stress on the environment has many forms -- agricultural practices, timber harvesting, domestic animal grazing, industry, hunting, predator control, and pollution. Often it is the interaction of numerous types of stress which results in the extinction of a species.

The primary causal factors of animal extinction include, but are not limited to: ecosystem alteration, introduction of exotic species, predator and pest control, pollution, poaching, and the capture of wild animals for legitimate and illegal purposes. Ecosystem alteration is one of the more significant causes of extinction. When wildlife niches are altered, animals must move to other areas, adapt to a new environment, or die. Even though some habitats are not totally destroyed, there may not be enough suitable area remaining to maintain a viable population. Habitat destruction is responsible for approximately 30 percent (%) of the presently endangered species (Uetz & Johnson).

Riparian habitat in the Southwest is a classic example of the effect man can exert on a particular habitat. Records of early explorers (Emory, 1948) reveal that riparian communities have been altered significantly from the original type. Significant man-caused impact on the riparian type began approximately 450 years ago, when European man first journeyed into the Southwest from Mexico. Early day grazing undoubtedly had an effect on riparian areas. In the last 100 years, the rate of alteration has increased significantly. This is due largely to ever-increasing human pressures, land clearing for agriculture, dam construction, grazing, pumping of ground and surface water for irrigation, and increased recreational pressures. For decades the primary or dominant use of riparian habitat in the Southwest has been water management; other values were not considered. The dominant use was to supply metropolitan areas with water.

1/ Paper presented at the Symposium on Importance, Preservation, and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

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Wildlife populations have adapted to survive in these alterations of the riparian type.

The importance of the riparian type for wildlife has been well documented, particularly for avian species. MacArthur (1964) established a correlation between bird species diversity (BSD) and floral height diversity (FHD). He also reported that habitats with permanent water had higher avian populations than those without. Johnson & Carothers (1975) recorded the highest population of non-colonial nesting birds ever reported in North America in a homogenous cottonwood stand along the Verde River in Arizona. Of the 70 breeding species investigated in the riparian type, 50% were obligate nesting species, 20% indicated a decided preference for the riparian type and 30% nested in either the riparian type or non-riparian without a significant preference for either type (Carothers & Johnson, 1975).

Gavin & Sowls (1975) found 476 pairs of nesting birds per 40 hectares in a mesquite (Prosopis juliflora) bosque in Southern Arizona. The adjacent habitat type was temperate and desert grassland. Balda (1967) found 31 and 46 pairs per 40 hectares (ha.) in the mixed grass and yucca-grassland types in Southern Arizona. Carothers (1974) found 332 pairs/40 hectares (ha.) in the mixed broadleaf type in the Verde Valley in Arizona. Beidleman (1960) and Hering (1957) reported 30 pairs per 40 hectares in the adjacent pinyon-juniper type. Obviously, bird densities are significantly higher in the riparian type than in adjacent communities.

Riparian vegetation enhances aquatic habitats through reduction of solar radiation, reduced erosion, decreased sedimentation, and energy input in the form of vegetational debris and terrestrial insects. Most of the food for important aquatic insects comes from land vegetation. Several studies show that these sources contribute a 50-70% of the energy responsible for producing fish in a stream. (Fisher & Likens, 1973).

Riparian habitats have three basic prerequisites for wildlife: food, water, and cover. The cover component has proportionately more ecotones than any other type. Ecotonal areas are a result of horizontal and vertical stratification of deciduous and evergreen trees, water and hydrophilic plants, and the undulating configuration of the type. Vertebrates that either live or reproduce in water are confined to these zones. Riparian habitats receive proportionately more use per unit area than any other type. A large percentage of terrestrial species known to occur in a given area are either directly dependent on riparian zones or utilize them proportionately more than any other habitat type. In short, the riparian type is the most important habitat type in the Southwest for wildlife.

A substantial volume of literature documenting the importance of the riparian type has been published but some key questions need to be answered prior to initiating a realistic attempt to manage this type.

1. What floristically is a riparian community?

2. Where is it located and what is its ecological condition?

3. What are the ecological factors limiting perpetuation of the community?

4. Is the community maintaining itself through natural reproduction? If not, what are the factors preventing perpetuation?

5. What should our management objectives be for riparian habitat? Water production, habitat for wildlife, water quality, recreation, fuelwood, aesthetics, fisheries, grazing, and agriculture are all potential uses of the riparian type.

6. What is the species composition and age class of a healthy riparian community?

Verbose definitions of what constitutes a riparian type abound in the literature, but, simply stated, it is an aggregation of floral species which depend on a flow of water on or near the surface for subsistence. Riparian habitat occurs in every life zone in Arizona with the possible exception of the Hudsonian. Species composition changes with elevation. Often the climatological conditions prevalent in drainageways allow the downward extension of a higher elevation species such as ponderosa pine (Pinus ponderosa) fingering down a canyon into the Upper Sonoran Life Zone. These inclusions are ecologically important as they provide an additional ecotone within the arid Upper Sonoran Life Zone and should properly be classified as a riparian community.

These riparian communities should be mapped and classified as to type and condition rating. Until we know where they are and what their ecological condition is, we cannot manage them. This should be an integral compon-

ent of our planning process.

Prior to implementation of any type of management, the most critical need is knowledge of the ecological requirements of individual plant and animal species for self propagation. It is not realistic to believe that we can artifically maintain a vegetative type through perpetuity. Classification of riparian communities and documentation of their condition class will reveal whether or not these communities are maintaining themselves. If not, the next logical step is to carefully determine what are the causal factors. Generally speaking, failure of the riparian type to regenerate itself in Arizona can be related to several factors either operating independently or in conjunction with one another.

1. Loss of water flow as a result of diversions for irrigation, impoundments for metropolitan usage, and lowering of water tables by pumping for sundry uses.

2. Loss of significant portions of entire communities as a result of devestating floods. These periodic floods are significant because they remove substantial numbers of older mature trees which serve as seed sources. Many of the riparian species are adapted to periodic flooding and an occasional flood is necessary for germination and survival of the seedlings, but floods of a significant magnitude are detrimental.

3. In areas of high recreational use, soil compaction, trampling, and inability of the soil to retain moisture prevent seedling establishment. Also, loss of ground vegetation (herbaceous) dries out the site and prevents regeneration of some species.

4. Phreatophyte control essentially eliminates the vegetation, removes the seed source, and changes the micro-site relationships.

5. Overgrazing by domestic livestock, in my opinion, is probably the major factor contributing to the failure of riparian communities to propagate themselves. Continued overuse of riparian bottoms eliminates essentially all reproduction as soon as it becomes established. Overstocking and the consequent loss of vegetative cover on the adjacent watersheds is probably the main reason for the frequency of high intensity floods resulting in drastic changes in the density and composition of riparian bottoms.

An evaluation of a riparian community necessitates making a judgment of whether the type is in good, fair, or poor condition. In the Southwest we are talking about many different species aggregations within the riparian type. Significant research data is needed to answer some of these questions:

a. Should a certain percentage of the vegetation be comprised of a particular species?

b. What should the age class distribution be in a healthy stand?

c. What is an ideal canopy coverage in percent?

d. What should the composition and density of herbaceous vegetation be?

e. Does a particular site have potential to develop a riparian community under proper management?

Research has been initiated here in the Southwest in an attempt to answer some of these questions. During the interim we have developed the following scorecard to use in our evaluations.

RIPARIAN STAND ANALYSIS

This rating of the riparian habitat will be based principally on its attraction to associated wildlife and ecological stability of the type.

The 100-point transect described for browse and the aspen stand analysis will be used. Certain modifications in the technique and score card will make it adaptable for the riparian type. A description of this technique follows:

A. Mapping

Riparian types will be delineated on aerial photographs.

B. Establishing Transects

1. Riparian types to be analyzed will be sampled with paced condition transects.

2. Transect locations will be carefully selected to fall within representative portions of the type.

3. Additional transects will be run in the same stand whenever a change in condition is recognized.

4. Within the stand to be sampled, select a route and pace interval that will

provide a good cross section of the stand. The starting point should be identified and pin pricked on an aerial photo.

5. Pace along the chosen route, walking as straight as practically possible. Along a meandering stream course, cross back and forth across the channel but do not take sample points in the channel.

6. At each sample point, record whatever is found with a 3/4 inch loop immediately in front of a mark on the boot toe. This may be bare ground or erosion pavement, rock, litter, grass, or forb. Grasses and forbs will be identified and tallied by individual species when all or part of the live root crown falls inside the loop. Record as litter if more than one-half of the loop covers dead plant material older than that resulting from current growth. Record hits on rock only for rock in place. Small, loose moving rock should be tallied as erosion pavement.

7. At each sampling point, the examiner will record, by species, the nearest woody riparian plant to the boot toe that occurs within a 180 degree arc in front of the sample point ("hit"). If the species involved can be described in timber terminology as a sprout (less than 4½ feet tall), a sapling (4½ feet tall to 4.9 inches diameter breast height d.b.h.), a pole (5 inches to 8.9 inches dbh), or mature (over 9 inches dbh), it should be tallied as such. If, however, the species involved is mature (at 4 inches dbh), the observer should use his best judgment on where the specimen of that species fits into the above described sale (i.e., if a species is mature at 4 inches dbh and one is "hit" that is 3 inches dbh., it should be tallied as a pole, not as a sapling.) If a dead riparian species is "hit", tally it and then record the size class for the nearest live riparian species. This will result in a transect sample of 100 live riparian species. If a riparian species is a sprout, determine if the sprout has been browsed or not. Dot tally this information on the appropriate column.

8. At each tenth sampling point, obtain the basal area and crown density of all woody species. Crown density will be taken with a spherical densiometer. Count each corner which intersects an opening in the canopy. Each corner represents approximately 6% of the total canopy. Multiply the number of corners which intersect openings by 6 and subtract this figure from 100 for crown density percentage. Basal area will be computed in the following manner: using a 1/100th acre plot (11'9" radius) record the dbh of all woody species at breast height and dot tally into the following size classes. All specimens greater than 12" dbh will be recorded individually by species. Basal area in sq. ft/ acre will be computed by using standard basal area tables.

9. At each tenth sampling point, a 1/100-acre pellet group plot will be run. Include all countable groups for deer, elk, cattle or horses.

C. Composition

"A species" (must be 4 or more) making up 75% or more of the composition. = H

"A species" (must be 2 or more) making up 35% or more of the composition. = M

"A species" comprise less than 35% of the composition or only one "A species" represented. = L

Species Rating - A

Cottonwood	Ash	Mulberry
Sycamore	Willow	
Walnut	Alder	
Hackberry	Elm	
Grape	Box Elder	
Rhus	Oak	

D. Crown Density

Crown density, as utilized in this particular scorecard, serves as a criterion of relative dominance, of potential productivity, of the influence of plants on precipitation interception and soil temperature, and of the value of vegetation to animals. It is applicable to almost all ecosystems, owing to the universal importance of light coming from above.

Crown density will be taken with a spherical densiometer. Count each corner on the grid which intersects an opening in the canopy. Each intersection represents approximately 6% of the total canopy. Multiply the number of intersections which occur in openings in the canopy by 6 and subtract the result from 100 for crown density percentage.

Crown Density Rating Guide

80%-100% = High (H)
50%-80% = Medium (M)
0-50% = Low (L)

E. Basal Area

Basal area refers to a comparison of species as to the aggregate cross-sectional area of the individual plants taken at or near ground

level, per unit of land area. Basal area gives a relative indication of dominance and biomass (by species) for the riparian community.

Basal area will be computed utilizing a 1/100th acre plot (11'9" radius) at each tenth sampling point. Record the d.b.h. of all woody species at breast height and dot tally into size classes. All specimens greater than 12" d.b.h. will be measured and recorded individually by species. Conversion factors for all d.b.h. size classes from 0"-12" are included on the scorecard. For those species greater than the 12" d.b.h. use the standard basal area tables included in the handbook.

Basal Area Rating Guide

60 sq. ft/acre or greater = High (H)
30 sq. ft/acre - 60 sq. ft/acre = Medium (M)
0-30 ft. sq/acre = Low (L)

F. Vigor

Vigor is determined by utilizing three (3) criteria: (1) the percentage of "A species" which are sprouts, (2) the percent of "A species" sprouts which have been browsed, (3) the number of "hits" on dead "A species." Summarize data for each measurement, apply to Riparian Vigor Rating Guide and indicate appropriate vigor rating (L-M-H) on the riparian scorecard. (See example below)

Riparian Vigor Rating Guide

Riparian type has at least 10% sprouts/ seedlings of "A species"	and	No more than 25% of the sprouts/seed- lings are browsed	and No more than 10 "hits" on dead ripar- ian species
Riparian type has over 5% sprouts/seed- lings of "A species"	and	No more than 75% of sprouts/seed- lings are browsed	and No more than 30 "hits" on dead ripar- ian species
Riparian type has less than 5% sprouts/ seedlings of "A species"	or	More than of sprouts/ seedlings are browsed	or "Hits" on dead ri- parian species exceed 30

G. Stand Structure

The age class distribution of "A species" determines the stand structure rating which will be applied to a riparian stand. This rating is based on the percentage of sprouts and saplings in relation to poles and mature "A species". Summarize this percentage and apply to the Riparian Stand Structure Rating Guide and indicate score on Form.

Riparian Stand Structure Rating Guide

All age classes represented with sprouts/seedlings and saplings of "A species" making up 30% or more of the stand. = H

At least 3 age classes represented with sprouts/seedlings and/or saplings of "A species" making up 10% or more of the stand. = M

Less than 3 age classes of "A species" represented with sprouts/seedlings and/or saplings of "A species" making up less than 10% of the stand. = L

The key question that needs to be answered is what should our management objectives be for the riparian habitat? Should the management objective be identical for all the riparian type, or should they be tailored to fit different species aggregations?

The riparian type has many potential uses but our primary objective should be to maintain the type in a healthy ecological condition, a condition which enables natural perpetuation of the community. It should be managed as the most sensitive habitat in the Southwest. This is particularly important because it is an area of maximum potential conflict between resources such as timber, wildlife, grazing, recreation, and water production. Past management has tended to overlook or disregard the intangible or non-economic uses of the community. Public land management agencies, partially as a consequence of public pressures, have had difficulty recognizing uses that are superficially lacking in tangible economic benefits. The dominant use of riparian type has been grazing and water production with little thought given to its value for wildlife and recreation or preservation as a unique community.

In order to evaluate management alternatives, an investigation of potential benefits versus ecological consequences is needed. Multiple use management should not assume that all uses should necessarily occur on the same acre of ground. Typically, management objectives are complicated by a variety of environmental situations and conflicting demands on resources.

If our management objective is to maximize the net gain in usable water, we should treat the upper watersheds and eliminate the riparian vegetation along the stream channel. Heindle (1965) estimated that we were harvesting ap-

proximately 5 million acre feet of surface water annually in Arizona, New Mexico and western Texas and predicted this amount could be doubled by treating upper watersheds, eradicating all riparian vegetation, suppressing evaporation from reservoirs, salvaging excessive surface water, diversions, and capturing uncontrolled streamflow.

Predictable amounts of water salvaged as a result of the complete removal of riparian vegetation have not been thoroughly documented. Estimates vary with different studies: Culler (1970) estimated an approximate savings of 0.8 acre/ft. per acre when dense tamarix (Tamarix Pentandra) and mesquite were completely cleared. Bowie and Kam (1968) estimated that complete removal of 22 acres of cottonwood (Populus fremontii), willow (Salix. spp), and seepwillow (Baccharis spp.) would salvage approximately 1.7 acre ft./acre or a savings of 6 percent of the inflow. Converting 15 acres of riparian shrubs and trees to grass in Southern California increased water yield 17 acre feet (1.1 acre ft./acre) in eight months (Rowe, 1963). Average water savings in certain habitat types is approximately 1 to 2 acre ft./ acre (Horton & Campbell, 1974).

Control of riparian vegetation for water production appears to be most feasible on flood plains where the water table is between 8 to 20 feet in depth and on upper watersheds above 7,000 feet in moist coniferous sites. Removal of riparian vegetation along perennial streams is probably not economically feasible because evaporation exceeds transpiration (Horton & Campbell, 1974).

Several logical assumptions can be postulated from the aforementioned studies: (1) removal of riparian vegetation increases surface flow but to what degree depends on the species, composition, and density; (2) increases in surface flow are modest because of the attendant increased surface evaporation; (3) re-treatment of the site is necessary as a result of reinvasion. (Campbell, 1970)

Evaluating the data brings to mind an interesting hypothesis. If we assume that water is a natural resource and the demand for water in large metropolitan areas for municipal and industrial uses will increase significantly, the price of water will also increase. If the demand is such that we need to increase our water yields we can accomplish this task and also improve the condition of our riparian habitat if we concentrate our efforts on the upper forested watersheds and the floodplains below 3500 feet with dense stands of mesquite or tamarix.

Dortignac (1965) reported maximum water yields emanate from forested high-elevation watersheds. He estimated that, in the Rio Grande Basin in New Mexico, 32 percent of the total water yield comes from the spruce-fir-aspen forest above 8,000 feet, while 40 percent is derived from the ponderosa pine forest. Horton & Campbell (1974) suggested that phreatophyte control is most effective on floodplains in lower elevations which support a dense stand of phreatophytes.

Riparian habitat that occurs between 7000-3500 feet in elevation has the highest ecological diversity, the greatest value to wildlife, and is the most abused by overgrazing. Increased streamflow through this elevational zone as a result of treatment in the upper watersheds would, if accompanied by reductions in domestic livestock, change some ephemeral streams to perennial, enhance regeneration potential as a result of increased moisture conditions, enhance density and vigor, improve aquatic habitat, and reduce stream temperatures as a result of more shading. Riparian vegetation in this zone, in most cases, is relatively sparse. Increasing the streamflow would increase the density of vegetation with an attendant increase in the amount of water lost through evapotranspiration. However, if this anticipated increase flows into perennial streams with a dense stand of riparian vegetation, no significant increase in evapotranspiration is predicted. (Campbell, 1970)

What would be the consequences of maximizing water yields without mitigating for other resources? The answer must be speculative, but the following results can be visualized:

1) All riparian plants will be temporarily suppressed.

2) Erosion and sedimentation will increase significantly because stream banks will lack vegetation for stabilization.

3) Transpiration losses will be negligible, but evaporation from the soil will increase as a result of higher soil temperatures and shallower water tables.

4) Rate of siltation of downstream reservoirs will increase.

5) Degradation of aquatic habitat will occur as a result of:

a. increased water temperatures

b. loss of energy from vegetational debris

c. loss of niches for aquatic insects

d. increased algae growth

6) Riparian habitat for wildlife will be lost; many species would be completely extirpated.

7) Aesthetic quality would be significantly diminished.

8) Potential recreational opportunities would be eliminated.

9) Potential for torrential type floods will increase.

10) Forage and cover for domestic livestock would be reduced.

What management strategies and alternatives are available if the stated objective is to manage the riparian type for production of domestic livestock? Obviously, the riparian type consists of many different aggregations of species, occurs within many habitat types, and is subjected to numerous management situations. Management strategies must, because of the diversity of the type, be referred to in a general sense. There is no panacea which is applicable to all situations.

Logically, prior to proposing a management strategy we need to know: What are the problems and what are the desired consequences? The problem is that the riparian areas are in poor condition, particularly when their potential productivity is considered. In order to correct a problem, one needs to determine what was/is the cause. Overgrazing by domestic livestock, in my opinion, is the obvious answer. The desired consequence is to create a situation within the riparian type which will support an optimum number of domestic livestock on a sustained basis. This implies maintaining a suitable forage base through perpetuity to support livestock numbers for future generations.

The effect overgrazing has had on the riparian type is twofold: 1) increased potential for devastating floods due to elimination of vegetative cover on adjacent watersheds; 2) removal of herbaceous material and seedlings and/or sprouts of woody riparian in the bottoms. Consequently, the following situation exists:

1) failure of the type to reproduce itself;

2) poor representation of age classes;

3) low vigor;

4) lack of sufficient vegetative cover to prevent erosion;

5) elimination due to channel-scouring floods of older mature trees which constitute critical seed sources;

6) elimination of moist microsites required for reproduction of such species as sycamore (Platanus wrightii);

Proper stocking on adjacent watersheds is needed to reduce both the volume and frequency of flooding. If this cannot be accomplished, efforts to obtain reproduction in the riparian type will not be as effective.

An expedient procedure to rejuvenate riparian stands is to exclude livestock by fencing until reproduction is out of reach. In steep canyons this can be accomplished easily because of restricted accessibility, but in other areas many miles of fence would be required. Riparian species are prolific growers. If conditions are amenable to growth, cotton (Populus spp.), alder (Alnus spp.) and sycamore can grow 10 to 15 feet in several years if protected from grazing.

Once re-establishment has occurred, grazing under a rest-rotation management program accompanied by proper utilization factors, salting and riding can be utilized to maintain the optimum species composition for a sustained yield of domestic livestock.

Anticipated environmental and social consequences of managing the riparian habitat for domestic livestock are:

1) a significant reduction in stocking rates would temporarily have an adverse economic effect on many livestock operators;

2) decreased flooding potential;

3) improvement of terrestrial and aquatic habitats;

4) reduced erosion and sedimentation;

5) improvement in water quality;

6) reduction in water yield;

7) retention of long term site productivity;

8) improved forage production for domestic livestock;

9) enhanced recreational opportunities;

10) increased esthetic quality;

Management of the riparian habitat for wildlife could best be accomplished by the total exclusion of domestic livestock with the exception of water gaps for watering purposes. A theoretical exception whereby periodic grazing would be beneficial would be a marsh area occupied by nesting waterfowl. Dense vegetation along the periphery should be eliminated periodically by grazing to retain a terrestrial herbaceous food source. A logical question as regards a recommendation to exclude livestock would be: Can livestock be prudently utilized to maintain a desirable understory composition? Realistically, the time necessary to restore the riparian habitat to a healthy condition is decades. The potential use of livestock to manipulate vegetation in the riparian habitat may be worthy of consideration in 30 years. Horizontal and vertical stratification, diversity of floral species, and floral volume is needed for optimization of wildlife habitat -- regardless of what is done, this will not be realized for many years.

Environmental consequences of managing riparian habitat for wildlife are essentially the same as listed for managing for livestock with the following exceptions:

1. Adverse economic effect would be permanent, i.e., production of domestic livestock from the riparian type.

2. Forage production for livestock would not improve because they would be excluded.

3. Reduction in water yield would increase.

Management for recreation would utilize the procedures mentioned for wildlife, but access should be provided by trails, campgrounds, etc. Environmental consequences are the same.

Riparian habitat in the Southwest is rapidly dwindling. Land managers need to initiate management to stop the rate of loss and insure the perpetuation of the community.

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Endangered Species vs. Endangered Habitats: A Concept[1]

R. Roy Johnson[2], Lois T. Haight[2], and James M. Simpson[3]

Abstract. - Although the great diversity within riparian ecosystems was recognized earlier, their extreme productivity was not discovered until this decade. The highest densities of nesting birds for North America have been reported from Southwest cottonwood riparian forests. Complete loss of riverine habitat in the Southwest lowlands could result in extirpation of 47 percent of the 166 species of birds which nest in this region.

INTRODUCTION

Since 1600 more than 120 bird and mammal species have become extinct while more than 300 are now threatened (Fisher et al. 1969). In addition, dozens of fishes, amphibians and reptiles have become extinct or are endangered to say nothing of invertebrate species. Habitat disruption and destruction have been a major cause of extinction. Only 24 percent of the birds and 25 percent of the mammals became extinct through natural causes. Of the 76 percent of the birds and 75 percent of the mammals which died from human related causes, well over half have been through indirect means, such as introduction of exotic speices and habitat disruption (Fisher et al. 1969 and IUCN Red Data Books issued periodically).

In an attempt to reduce the numbers of species which will soon become extinct, several steps have been taken. A major step involves the formation of recovery teams, comprised of authorities on a given species, such as the Bald Eagle. The activities of these teams have apparently been beneficial in slowing down rates of loss in wildlife species. However, the efforts of recovery teams cannot possibly prevent continued extirpation if we continue to disrupt habitat through activities such as overgrazing, urbanization, "modern, clean" agricultural practices, dam construction and channelization. Continued research is needed to provide answers to questions posed by management regarding means through which critical wildlife habitat may be preserved.

DISCUSSION

Extirpation

The extirpation of wild animal species has been a cause for concern for decades. People only mildly interested in conservation can bring to mind the examples of the Passenger Pigeon (Ectopistes migratorius - extinct 1914), the Carolina Parakeet (Conuropsis carolinensis- extinct 1914), the Dodo (Raphus cucullatus- extinct 1681) and the Great Auk (Pinguinus impennis - extinct 1844). Dates for extinction are from Pettingill (1970) and Van Tyne and Berger (1971). An entire book has been written about the Passenger Pigeon (Schoerger 1955) and people are still trying to find out whether or not the Ivory-billed Woodpecker (Campephilus principalis) is now extinct. Several recent books have been written appealing to citizens of the world to help save these rapidly diminishing species (Greenway 1958, Fisher et al. 1969, Prince Phillip and Fisher 1970, Simon and Geroudet 1970, Tylinek and Ullrich 1972, and Ziswiler 1967). Information from the International Union for Conservation of Nature and Natural Resources (I.U.C.N.) Red Data Books (issued periodically) presents a dismal picture (Table 1).

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1 Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

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Table 1.--A history of species' extirpation. (adapted from I.U.C.N. Red Data Books)

Date	Number of extinctions	Direct[1]	Indirect[2]
1600s	21	86%	14%
1700s	36	84%	16%
1800s	84	24%	76%
1900-1974	85	28%	72%

[1] Direct = Hunting for food or commercial causes.

[2] Indirect = Habitat disruption, introduction of exotics, etc.

Attempts to Prevent Extinctions

The concern over the increasing numbers of species being exterminated in the United States caused the U.S. Fish and Wildlife Service to begin work on classification of "threatened" wildlife in the early 1960's. The 1st edition of the "Redbook" was issued in July 1966. We use the words "threatened" and "endangered" in an unofficial sense (see U.S. Fish and Wildlife Service 1973 for official definition). Endangered species are assigned in the United States according to the Endangered Species Conservation Act of 1969 and listed periodically in the U.S. Federal Register by the U.S. Fish and Wildlife Service. It is not our intent to go into great depth regarding endangered speices programs. The forementioned I.U.C.N., U.S. Fish and Wildlife Service and others (e.g. American Committee on International Wildlife Protection, National Audubon Society and World Wildlife Fund) publish periodic information on endangered wildlife (e.g. Arbib 1976). Other governmental agencies besides the U.S. Fish and Wildlife Service publish information regarding endangered wildlife (Arizona Game and Fish Department 1977[4], Behnke and Zarn 1976, U.S. Forest Service 1975, U.S. National Park Service 1974). Symposia are held periodically focusing on general problems of endangered wildlife (New Mexico Game and Fish Department 1972) or even devoted to a single species such as the Peregrine Falcon (Falco peregrinus) (Hickey 1969) or the Red-cockaded Woodpecker (Dendrocopos borealis) (Thompson 1971). Periodically, reports are issued on endangered species such as the Southern Bald Eagle (U.S. Fish and Wildlife Service 1976). Recovery teams to address the problem of impending extinction have been set up by the U.S. Fish and Wildlife Service for many species of endangered wildlife. For example, several avian species are now being raised by methods of direct intervention such as egg manipulation (Zimmerman 1976). In addition, several agencies are now involved in establishing endangered plant lists.

In addition to teams concerned with the protection of terrestrial wildlife, such as the Peregrine Falcon and Southern Bald Eagle, other recovery teams have been organized to focus on one or more fish species. Recently, however (Johnson[5]) the U.S. Fish and Wildlife Service has designated teams which focus on river systems instead of individual species, e.g. the Colorado River Fishes Recovery Team. This approach has been advocated for years by many of us who have seen the wholesale extermination of species in certain areas as a result of habitat destruction. Nowhere is this chain of destruction more certain than in riverine ecosystems. This has long been recognized by ichthyologists such as Deacon and Minckley (1974), Holden and Stalnaker (1975), Minckley and Deacon (1968) and Sigler and Miller (1963).

Glen Canyon Dam: An Example

The construction of Glen Canyon Dam on the Colorado River above Grand Canyon is an outstanding example of habitat modification. The effect on the aquatic ecosystem has been devastating. The original heavy silt burden which rendered the Colorado River "too thick to drink and too thin to plow" is dropped in Lake Powell before the water enters Grand Canyon. The river waters are now clear. The reddish color for which the Colorado was named can be seen only after flooding from tributaries which enter below the dam. This has created an entirely new riverine ecosystem (Carothers et al. in press, Dolan et al. 1974 and in press, Johnson and Martin 1976,and Laursen and Silverston 1976). The management implications are staggering. On one hand, a new riparian ecosystem has developed, protected from the scouring and siltation of pre-dam floods. On the other hand this white water river has been converted from a stream which was warm in the summer and cold in the winter to a relatively constant 9-10°C (48-50°F) along most of its length. The only insect family recorded using these cold waters are Chironomid midges (Stevens 1976) while the

[4] Arizona Game and Fish Department. 1977. Endangered and threatened species in Arizona; 3 p. memo

[5] Johnson, J. Paper presented at New Mexico-Arizona section meeting, the Wildlife Society, Farmington, N.M., Feb 5, 1977.

small crustacean, Gammarus lucustris, abounds. The cold, clear water is conducive to the rapid growth of exotic species such as rainbow trout, which commonly reach lengths of more than 2 feet and weigh over 5 pounds (personal observation). While exotic fish flourish, our native species are declining. In the 277 miles of the Colorado River in Grand Canyon National Park several species listed in Fishes of Arizona (W. Minckley 1973 and pers. comm.) occur either in low numbers, or cannot be found at all, e.g. the Humpback Chub (Gila cypha), Bonytail Chub (G. elegans), Colorado Squawfish (Ptychocheilus lucius) and Razorback Sucker (Xyrauchen texanus) (Johnson 1977, C. Minckley and Blinn 1976, Miller 1975[6], and Suttkus et al. 1976).

Endangered Species and Related Acts

When the Endangered Species Act of 1973 (PL #93-205) was passed it was hoped by many of us concerned about extirpation of wildlife that this might prevent further wholesale extinctions through degradation of habitat. It seemed that the Endangered Species Act combined with the National Environmental Policy Act of 1969 (PL #91-190) should slow down direct extermination as well as massive destruction of the type that has converted nearly all southwestern rivers to poor or impossible habitat for most native species. Just how effective these laws will be remains to be seen. Legal decisions involving the case of the Tennessee Valley's Tellico Dam on the Little Tennessee River vs. the Snail Darter (Percina tanasi) may have important implications regarding the future interpretation of Section 7 of the Endangered Species Act, including possible amendation by congress (Holden 1977).

It seems inevitable that riverine ecosystems will become the battleground for those advocating the "progress of civilizing processes," e.g. hydroelectric and irrigation projects. Economic interests oppose those who advocate saving a few rivers to protect associated wildlife and recreational values and perhaps, "just to let them run."

The two forementioned acts coupled with the Wild and Scenic Rivers Act of 1968 (PL #90-542) would seem to be sufficient to reduce further decimation of river ecosystems. However, it is a difficult, uphill battle. Prevention of the use of streams for waste disposal is gradually becoming an accepted philosophy. Conversely, industrial, domestic and irrigation demands for water for a growing population continue to escalate.

Major Causes of Habitat Loss

The impact of dams on aquatic ecosystems has long been understood by biologists even if ignored by dam builders and water users. The area above the dam is converted into a lake, rapidly filling with sediment. The area below the dam too commonly becomes a dry stream bed, as is the situation with most of the Salt and Gila River dams of the Lower Colorado River drainage. Neither habitat is conducive to most of the pre-dam riverine plants or wildlife. Other rivers are greatly reduced in volume by practices such as pumping of underground water which dries up spring sources, or by modification of runoff patterns through overgrazing. The latter often results in the development of vegetation types which demand more water than the original vegetation. The area may be denuded, resulting in flash floods followed by quick drying up of streams rather than a slower, steady runoff. The effects of such practices on native fishes have been well documented (Minckley and Deacon 1968). However, we have only recently begun to understand the impacts on riparian ecosystems.

Recent work by various investigators (Boster and Davis 1972, Clary et al. 1974, and Hibbert et al. 1974) advocates the conversion of shrub types, commonly resulting from overgrazing, to grassland. This conversion to grassland usually results in increased water yield which, in turn, often results in an increase in acreage of riparian vegetation (personal observation, Sierra Ancha and Three Bar watersheds).

Some investigators propose large scale "phreatophyte control" projects as well as the conversion of shrub types to grassland (see Ffolliott and Thorud 1974 for discussion). These "water salvage" projects are often advocated even at the expense of both game and nongame wildlife values. Earlier work commonly featured "pure" scientists as well as "applied" scientists, all concentrating on single purpose management of watersheds and their runoff for man, his farms and cattle (Barr 1956, Duisberg 1957, and Warnock and Gardner 1960). In recent years there has been a gradual trend toward multiple use of this critical resource, water (Horton and Campbell 1974). The Arizona Annual Watershed Symposia reflect this change in philosophy (Arizona Water Commission; annually)

6 Miller, R.R. 1975. Report on fishes of the Colorado River drainage between Lees Ferry and Surprise Canyon, Arizona. Unpublished Grand Canyon Natl. Park Res. Rpt. 6 p.

placing increasing emphasis on wildlife values, recreation and even aesthetics (Arizona Water Commission 1972).

Riparian Exploration, Development and Research

It seems incredible that man would so badly mistreat riverine ecosystems. We have used them for exploratory routes, fur trapping, temporary settlements and forts, agricultural land and cities. Finally, we have dammed them up, dried them up, and turned them into sewers and garbage disposals.

Early explorers commonly were army officers, geologists, engineers or "soldiers of fortune" who left incomplete to poor records regarding the riparian habitat. This is true throughout the Southwest. Thus, early notes from rivers such as the Gila (Emory 1858) and even the mighty Colorado (Powell 1961) often mention vegetation and wildlife only in general terms. We do not even have good species' lists for the pre-dam ecosystems, much less information on population densities or other more sophisticated data. Even as late as the 1950's (Woodbury et al. 1959) scientists gathered information regarding the area to be inundated by Lake Powell, above Glen Canyon Dam. However, the more than 250 miles of river between Glen Canyon Dam site and the upper reaches of Lake Mead, which were also to be heavily impacted by the dam, were totally ignored.

Riverine environments, including their riparian ecosystems, have been ignored by biologists as well as geologists, explorers and laymen for many reasons. Riparian ecosystems have several characteristics which make them interesting but involved, difficult systems to study. Riparian habitat may be considered an ecotone between the aquatic habitat of the stream itself and the surrounding terrestrial habitat. As such, the riparian ecosystem contains elements of both the aquatic and terrestrial ecosystems plus retaining unique characteristics found in none of the other ecosystems exemplifying the edge effect. The concept of the edge effect is relatively new. Earlier treatises did not even mention this phenomenon and it was not until the mid-1900s that ecology texts, e.g. Allee et al. (1949) contained a discussion of the edge effect. Odum (1959) defines the edge effect as "the tendency for increased variety and density at community junctions."

Ornithologists and birders have long recognized the importance of riparian habitats to birds. We chose at random 20 inland Christmas Bird Counts for 1974 (National Audubon Society 1975). Nineteen (95%) of the 20 contained streamside and/or lake side vegetation. The large number of species utilizing riparian woodland has been documented by numerous studies (Carothers and Johnson 1975b). In California, Miller (1951) emphasized the importance of riparian avifaunas, stating "the number of species of birds associated with riparian woodland is larger than that of any other formation." However, the extremely high densities of riparian avian populations was not recognized until this decade (Carothers et al. 1974, Carothers and Johnson 1971 and 1975b, Gaines 1974, Johnson 1970, O'Brien et al. 1976, and Table 2).

The ecological analysis of riparian birds is complicated at best. Studies are further complicated by recent changes, some of which are related to man's activities and others which may be operating independently of man. One cannot help postulating however, that nearly all of the recorded recent changes are due to man's activities. For example, there are records for the arrival of several species of birds which have moved into Arizona as breeding species within historic times. This includes the Mississippi Kite, Inca Dove, Thick-billed Kingbird, Starling, House Sparrow, Great-tailed Grackle and Bronzed Cowbird. The Starling and House Sparrow are European introductions. The Inca Dove, Great-tailed Grackle and Bronzed Cowbird are closely associated with man and his animals. Their movements are discussed by Phillips et al. (1964) and Phillips (1968). Other cases are not as clear but may have profound effects on the native avifauna. The subtleness with which human activity may affect the natural ecosystem can be shown through a discussion of the Brown-headed Cowbird. Phillips (1968) discusses at length the historic expansion of range by Brown-headed Cowbirds. Of the 33 species of Southwestern lowland birds listed by Friedmann (1929) as hosts to the Brown-headed Cowbird, 22 (2/3) are obligate or preferential riparian nesting species. The role of these brood parasites in reducing populations of riparian birds in the Sacramento Valley, California, is discussed by Gaines (1974). Thus, Brown-headed Cowbirds may be suspected of causing problems in Arizona and other southwestern areas similar to those reported for California.

SUMMARY AND CONCLUSIONS

During our recent analysis of the dependency of the breeding avifauna of the Southwest lowlands on water related habitat (Table 3), we discovered some sobering facts. 166 species of nesting birds were analyzed from southern Arizona, southern New Mexico and west Texas, south through the lower

Table 2. -- A comparision of breeding bird densities in selected habitats. (After Carothers and Johnson 1975b).

Habitat Type (Community)	Locality	Authority	Breeding Bird Density Males or Estimated Pairs/40 ha [or 100 acres] nonriparian	riparian
Boreal Forest[1]				
Spruce-Alpine Fir	Arizona	Carothers et al. (1973)	178	-
Temperate Forest				
Spruce-Douglas Fir	Arizona	Balda (1967)	380	-
Ponderosa Pine	Arizona	Balda (1967)	336	-
Ponderosa Pine	Arizona	Haldeman et al. (1973)	232	-
Mature Deciduous	West Virginia	Audubon F.N. (1948)	724 [2]	-
Virgin Spruce	West Virginia	Audubon F.N. (1948)	762 [2]	-
Forest Bird Sanctuary	Germany	Bruns (1955)	5600 [2]	-
Relict Conifer Forest				
Cypress post climax	Arizona	Johnston and Carothers (1975)	93	-
Riparian Deciduous Forest				
Mixed Broadleaf	Arizona	Balda (1967)	-	304
Mixed Broadleaf	Arizona	Carothers et al. (1974)	-	332
Cottonwood	Arizona	Carothers et al. (1974)	-	847
Cottonwood	Arizona	Ohmart (no date)	-	683
Flood-plain Deciduous	Illinois	Fawver (1947)	-	216 [2]
Temperate Woodland				
Pinyon-Juniper	Arizona	Hering (1957)	33	-
Pinyon-Juniper	Arizona	Beidleman (1960)	30	-
Encinal	Arizona	Balda (1967)	224	-
Subtropical Woodland				
Mesquite Bosque (riparian)	Arizona	Gavin and Sowls (1975)	-	476 [3]
Mesquite	Arizona	Ohmart (no date) [5]	236	-
Grassland				
Temperate Grassland	Arizona	Balda (1967)	64	-
Tropical Grassland	Tanganyika	Winterbottom (1947)	4000 [2]	-
Desert Grassland				
Yucca/Grassland	Arizona	Balda (1967)	31	-
Chihuahuan Desert Scrub				
Creosotebush	New Mexico	Raitt and Maze (1968)	8.5-17.7	-
Sonoran Desert Scrub				
Paloverde/Sahuaro	Arizona	Tomoff(1974 & pers.comm.)	105-150	-
Temperate Marshland				
Cattail Marsh	Arizona	Carothers and Johnson (1975b)	-	175-176
Cultivated, Urban and Suburban Lands				
Park (zoological garden)	Germany	Steinbacher (1942)	1170 [2]	-
Bird Sanctuary (Whipsnade)	England	Huxley (1936)	5800 [2]	-
Urban	Arizona	Emlen (1976)	1230 [2]	-
Cottonwood	Arizona	Carothers and Johnson(1975a)	-	605.2 [4]

1 Arizona vegetation types after Brown and Lowe (1974).

2 Density given in number of adult birds per 40 hectares (100 acres) instead of males or nesting pairs (after Welty 1962).

3 Average density for April and May, the height of breeding activity in the mesquite bosque.

4 Riparian cottonwood habitat disturbed by urbanization. Two years prior, when the habitat was undisturbed, the density was 1058.8 pairs/100 acres.

5 Ohmart, R.D. and N. Stamp. No date. Final report on the field studies of the nongame birds and small mammals of the proposed Orme Dam site. Bur. of Recl. Proj., Boulder City, Ariz. 54 ms. p.

Table 3. -- Nesting birds of the Southwest Lowlands (Modified from Haight and Johnson 1977)[1]

WETLANDS (2%)

Clapper Rail Rallus longirostris
Black Rail Laterallus jamaicensis
American Avocet Recurvirostra americana
Snowy Plover Charadrius alexandrinus

WETLANDS AND OBLIGATE RIPARIAN (19%)

Least Grebe Podiceps dominicus
Pied-billed Grebe Podilymbus podiceps
Double-crested Cormorant Phalacrocorax auritus
Olivaceous Cormorant Phalacrocorax olivaceus
Great Blue Heron Ardea herodias
Green Heron Butorides striatus
Great Egret Casmerodius albus
Snowy Egret Egreta thula
Black-crowned Night Heron Nycticorax nycticorax
Least Bittern Ixobrychus exilis
Black-bellied Whistling-Duck Dendrocygna autumnalis
Mallard Anas platyrhynchos
Mexican Duck Anas diazi
Gadwall Anas strepera
Blue-winged Teal Anas discors
Cinnamon Teal Anas cyanoptera
Redhead Aythya americana
Ruddy Duck Oxyura jamaicensis
Osprey Pandion haliaetus
Virginia Rail Rallus limicola
Sora Porzana carolina
Common Gallinule Gallinula chloropus
American Coot Fulica americana
Black-necked Stilt Himantopus mexicanus
Killdeer Charadrius vociferus
Long-billed Marsh Wren Cistothorus palustris
Common Yellowthroat Geothlypis trichas
Yellow-breasted Chat Icteria virens
Yellow-headed Blackbird Xanthocephalus xanthocephalus
Red-winged Blackbird Agelaius phoeniceus
Song Sparrow Melospiza melodia

OBLIGATE RIPARIAN (26%)

1. Common Merganser Mergus merganser
2. Mississippi Kite Ictinia mississippiensis
3. Cooper's Hawk Accipiter cooperii
4. Zone-tailed Hawk Buteo albonotatus
5. Gray Hawk Buteo nitidus
6. Common Black Hawk Buteogallus anthracinus
7. Bald Eagle Haliaeetus leucocephalus
8. Spotted Sandpiper Actitis macularia
9. Red-billed Pigeon Columba flavirostris
10. Yellow-billed Cuckoo Coccyzus americanus
11. Violet-crowned Hummingbird Amazilia verticalis
12. Buff-bellied Hummingbird Amazilia yucatanensis
13. Broad-billed Hummingbird Cynanthus latirostris
14. Green Kingfisher Chloroceryle americana
15. Red-shafted Flicker Colaptes auratus cafer
16. Rose-throated Becard Platypsaris aglaiae
17. Tropical Kingbird Tyrannus melancholicus
18. Thick-billed Kingbird Tyrannus crassirostris
19. Kiskadee Flycatcher Pitangus sulphuratus
20. Black Phoebe Sayornis nigricans
21. Willow Flycatcher Empidonax traillii
22. Western Wood Pewee Contopus sordidulus
23. Vermilion Flycatcher Pyrocephalus rubinus
24. Northern Beardless Flycatcher Camptostoma imberbe
25. Bank Swallow Riparia riparia
26. Cliff Swallow Petrochelidon pyrrhonota
27. Bridled Titmouse Parus wollweberi
28. White-breasted Nuthatch Sitta carolinensis
29. Bewick's Wren Thryomanes bewickii
30. American Robin Turdus migratorius
31. Bell's Vireo Vireo bellii
32. Yellow-green Vireo Vireo flavoviridis
33. Tropical Parula Parula pitiayumi
34. Yellow Warbler Dendroica petechia
35. Hooded Oriole Icterus cucullatus
36. Northern Oriole Icterus galbula
37. Bronzed Cowbird Molothrus aeneus
38. Summer Tanager Piranga rubra
39. Blue Grosbeak Guiraca caerulea
40. Painted Bunting Passerina ciris
41. White-collared Seedeater Sporophila torqueola
42. Lesser Goldfinch Carduelis psaltria
43. Albert's Towhee Pipilo aberti

PREFERENTIAL RIPARIAN (26%)

1. Peregrine Falcon Falco peregrinus
2. American Kestrel Falco sparverius
3. Gambel's Quail Lophortyx gambelii
4. White-winged Dove Zenaida asiatica
5. Mourning Dove Zenaida macroura
6. Common Ground Dove Columbina passerina
7. White-fronted Dove Leptotila verreauxi
8. Greater Roadrunner Geococcyx californianus
9. Groove-billed Ani Crotophaga sulcirostris
10. Barn Owl Tyto alba
11. Common Screech Owl Otus asio
12. Ferruginous Pygmy Owl Glaucidium brasilianum
13. Lesser Nighthawk Chordeiles acutipennis
14. Black-chinned Hummingbird Archilochus alexandri
15. Anna's Hummingbird Calypte anna
16. Gila Woodpecker Melanerpes uropygialis
17. Golden-fronted Woodpecker Melanerpes aurifrons
18. Ladder-backed Woodpecker Picoides scalaris
19. Western Kingbird Tyrannus verticalis
20. Cassin's Kingbird Tyrannus vociferans
21. Wied's Crested Flycatcher Myiarchus tyrannulus
22. Ash-throated Flycatcher Myiarchus cinerascens
23. Rough-winged Swallow Stelgidopteryx ruficollis
24. Green Jay Cyanocorax yncas
25. Common Raven Corvus corax
26. Verdin Auriparus flaviceps
27. Northern Mockingbird Mimus polyglottos
28. Long-billed Thrasher Toxostoma longirostre

29. Curve-billed Thrasher Toxostoma curvirostre
30. Crissal Thrasher Toxostoma dorsale
31. Black-tailed Gnatcatcher Polioptila melanura
32. Phainopepla Phainopepla nitens
33. Common Starling Sturnus vulgaris
34. Lucy's Warbler Vermivora luciae
35. Lichtenstein's Oriole Icterus gularis
36. Brown-headed Cowbird Molothrus ater
37. Cardinal Cardinalis cardinalis
38. Pyrrhuloxia Cardinalis sinuata
39. Indigo Bunting Passerina cyanea
40. Lazuli Bunting Passerina amoena
41. House Finch Carpodacus mexicanus
42. Olive Sparrow Arremonops rufivirgatus
43. Rufous-winged Sparrow Aimophila carpalis

SUBURBAN AND AGRICULTURAL (4%)

1. Black Vulture Coragyps atratus
2. Rock Dove Columba livia
3. Inca Dove Scardafella inca
4. Barn Swallow Hirundo rustica
5. House Sparrow Passer domesticus
6. Great-tailed Grackle Quiscalus mexicanus

NON-RIPARIAN (23%)

1. Turkey Vulture Cathartes aura
2. Red-tailed Hawk Buteo jamaicensis
3. Swainson's Hawk Buteo swainsoni
4. Ferruginous Hawk Buteo regalis
5. Harris' Hawk Parabuteo unicinctus
6. Caracara Caracara cheriway
7. Prairie Falcon Falco mexicanus
8. Common Bobwhite Colinus virginianus
9. Scaled Quail Callipepla squamata
10. Great Horned Owl Bubo virginianus
11. Elf Owl Micrathene whitneyi
12. Burrowing Owl Athene cunicularia
13. Long-eared Owl Asio otus
14. Poor-will Phalaenoptilus nuttallii
15. Pauraque Nyctidromus albicollis
16. White-throated Swift Aeronautes saxatalis
17. Lucifer Hummingbird Calothorax lucifer
18. Costa's Hummingbird Calypte costae
19. Gilded Flicker Colaptes auratus chrysoides
20. Say's Phoebe Sayornis saya
21. Horned Lark Eremophila alpestris
22. Purple Martin Progne subis
23. White-necked Raven Corvus cryptoleucus
24. Cactus Wren Campylorhynchus brunneicapillus
25. Canyon Wren Catherpes mexicanus
26. Rock Wren Salpinctes obsoletus
27. Bendire's Thrasher Toxostoma bendirei
28. LeConte's Thrasher Toxostoma lecontei
29. Loggerhead Shrike Lanius ludovicianus
30. Eastern Meadowlark Sturnella magna
31. Western Meadowlark Sturnella neglecta
32. Scott's Oriole Icterus parisorum
33. Varied Bunting Passerina versicolor
34. Brown Towhee Pipilo fuscus
35. Grasshopper Sparrow Ammodramus savannarum
36. Lark Sparrow Chondestes grammacus
37. Rufous-crowned Sparrow Aimophila ruficeps
38. Cassin's Sparrow Aimophila cassinii
39. Black-throated Sparrow Amphispiza bilineata

166 Total

(Information from A.O.U. 1958, Bailey 1928, Bent-various dates, Hubbard 1970 and 1971, Johnson et al. 1973[2], Johnson et al.-manuscript[3], Monson and Phillips 1964, Monson-personal communications, Oberholser 1974, Phillips et al. 1964, Rea 1977, Todd 1975 and undated, Wauer 1973, and Wolfe 1956)

[1] Haight, L.T. and R.R. Johnson. Paper presented at annual meeting of the Arizona Academy of Science, April 17, 1977.

[2] Johnson, R.R., S.W. Carothers and D.B. Wertheimer, 1973. The importance of the Lower Gila River, New Mexico, as a refuge for threatened wildlife. Unpubl. Rpt. to U.S. Fish and Wildl. Serv., Albuquerque. 53 p.

[3] Johnson, R.R., J.M. Simpson and J.R. Werner. Unpublished manuscript. Birds of the Salt River Valley, Maricopa Co., Arizona

Rio Grande Valley. Habitats up through desert grasslands were considered, stopping at the lower edge of woodland and forests. 127 (or 77%) of the 166 nesting species were in some manner dependent on water related habitat. Of this 77% dependent on water related habitat well over half, 84 of the 166 species, are completely dependent on water related habitat. Only 39 species are non riparian nesting birds. Thus, if water dependent habitats were completely destroyed in the Southwest (not including suburban and agricultural) we could completely lose 47% of our lowland nesting birds while only 23% of our lowland nesting species would probably not be affected. 43 (26%) of the 166 species would be partially affected. Granted, several of the species which are preferential riparian at lower elevations, such as the Western and Cassin's Kingbirds, extensively use non riparian habitat at higher elevations. Still, the overall populations of these species would diminish with the reduction or loss of riparian habitat at lower elevations. In a dissertation on "Historic Changes in the Avifauna of the Gila Indian Reservation," near Phoenix, Rea (1977) uncovered the following information. Through the use of archaeological, ethnographic and historic sources he found that 101 species breed or have bred on the reservation with 5 more species that probably bred and 7 species that could have bred, based on biogeographic distributions. During the past 100 years, 22 breeding species were extirpated of which 18 were related to the former riverine ecosystem. Six speices of non-nesting birds dependent on the Gila River, now dry, are also gone. At least 13 species have recently recolonized the area as a result of reestablishment of a depauparate form of the original riparian habitat. This newly established habitat has developed as a result of the use of the Salt and Gila Rivers for disposal of effluent from the Phoenix sewage treatment plants.

Others, e.g. Hubbard (1972) have pointed out the lack of attention given to song birds when designating threatened and endangered species. However, to our knowledge, ours is the first attempt to quantify the number of species threatened or endangered by practices which greatly modify or destroy riparian habitat.

Some proponents of water salvage projects have pointed out that many breeding species of the Southwest lowlands are at the northern limits of their range. This, of course, is an attempt to justify phreatophyte control, channelization, dam construction, grazing and other practices which reduce riparian vegetation and consequently riparian wildlife. The main populations are found in Mexico for a large percentage of the birds that also occur in the Southwest lowlands. Thus, it is argued, even complete loss of riparian and marshy habitat should cause no great problem at the total population level for that species. No argument could be further from the truth. The destruction of riparian habitat in northern Mexico is progressing at an alarming rate. One need but drive a few hundred miles south from the United States-Mexico border to observe the frantic rate at which Mexicans are draining their streams and clearing riparian forests and woodlands in an attempt to feed a rapidly expanding population. One reads with nostalgia Sutton's book, "At a Bend in a Mexican River" (1972). His accounts from travels in Mexico only four decades ago tell of ferrying across rivers such as the Rio Purificacion and of the lush growth in the Valley of the Rio Corona. The riparian groves along these rivers are being cut at a rapid rate to make room for houses and fields. Rivers throughout Mexico as well as the United States are being dammed to provide water for municipal and industrial use and for large irrigation projects.

Thus, the same basic stages of "development of natural resources" which took place in the United States during two centuries promise to occur in Mexico in a matter of decades. When adding the available improved technology to Mexico's great wealth of natural resources, synergism may result. This may effect an even greater cummulative ecological disaster in a much shorter period of time than we have experienced in riverine ecosystems in the United States. Thus, when evaluating the ecological health of riparian species we must approach the problem from the standpoint of a systems analyst. One may start with his or her area of responsibility whether it be a few yards of small stream or several hundred miles of a large river. However, we must be cognizant of the resources up and downstream from our area. We must show concern for the entire drainage system, even if primary responsibility for its management rests elsewhere. The managers of resource plots, cities, counties, states, and countries need to recognize that streams commonly flow thru lands in different ownership and across political boundaries.

MANAGEMENT RECOMMENDATIONS

1. The riparian habitat is the most productive and possibly the most sensitive of North American habitats and should be managed accordingly. Due to the complexity of riverine ecosystems, scientists have only recently

developed techniques to document the importance of these ecosystems to wildlife.

2. In addition to the importance of riparian habitat from an ecological standpoint, other values include:

(a) Recreational uses including hunting, fishing (Meehan et al. this symposium) and bird watching.
(b) Reservoirs for preservation of gene pools and to allow recolonization of areas hit by disasters such as forest fires, severe droughts and storms.
(c) Aesthetic values including painting, photography and just looking, listening, smelling, etc.

Thus, recreational, wildlife, and aesthetic values should be weighed against other values and alternative uses. This is especially important in land use planning for a habitat which has high pressures from alternative uses such as water for industrial and domestic purposes, irrigation, grazing and urbanization.

3. Use interdisciplinary teams, including recreation specialists, economists, etc., to develop improved means for determining wildlife values. This is especially important in figuring cost-benefit ratios for determining the best use for an area. We hope there will never be a need for putting a dollar figure on everything in order to establish its "value." (What is the value of 2 or 3 days vacationing along a streamside?) However, economic values have been placed, in part, on recreation such as hunting, fishing, and "general rural recreation" (Davis 1967, and Martin et al. 1974). Attempts to quantify these values should make them more competitive with other uses, such as those mentioned in No. 2 (above).

4. Finally, encourage investigations to clarify areas of knowledge which are currently poorly, if at all, known. We have discussed the complexity of riverine ecosystems and further reasons for the late development of this area of ecology.

Problems which need to be solved include:

(a) The minimum area and suitable configurations necessary to retain both plant and wildlife values in different riparian habitats.

(b) The maximum distance which can separate islands of a given habitat type before the loss of wildlife species or a great reduction in populations occurs.

(c) Optimal as well as minimal requirements for enhancing wildlife values for a given habitat type. These include ground cover, trees and shrubs per hectare, foliage volume, plant species present, and disturbance types and frequencies.

We will close by quoting Carothers and Johnson (1975a),

> "Determining these factors may be the most important problem facing us today. All the 'threatened species recovery teams' we can possibly amass will not prevent many species from becoming extinct in their native habitat if we degrade their habitats past the point of no return."

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Riparian Research Needs[1]

David R. Patton[2]

Abstract.--Approximately 22 studies on riparian habitat are in progress in the western United States. Six categories of studies are needed to provide managers with data for making decisions about the riparian ecosystem. The concept of "validation sites" can be used in a team approach to solve plant and animal problems in the riparian zone.

INTRODUCTION

Riparian zones, characterized by mesic vegetation and more or less permanent surface water, contrast with adjacent semiarid or dry subhumid environments (fig. 1). Early settlers gravitated to these limited river and stream areas. As a result, ranches, farms, and towns all have taken their toll of riparian zones. Human population growth has increased this pressure in the years following settlement. Introduction of livestock, use of streamflow for irrigation, and construction of dams and roads have compartmentalized the riparian zone with varied but mostly harmful effects to native fauna. The importance of riparian vegetation to wildlife habitat has become apparent only in this decade. Even now its overall importance is not widely recognized.

A search of some 24,000 research resumes in the U.S. Department of Agriculture's Current Research Information System (CRIS) revealed 10 related to riparian habitat. CRIS information and other sources indicate 22 active studies (10 plant, 5 animal, and 7 combined) in the western United States. These figures show that riparian vegetation is not receiving research at a level comparable to its importance as wildlife habitat. A concentrated effort directed at specific problems with realistic goals is needed.

A problem analysis for Forest Service wildlife habitat research in the Southwest that identified riparian research needs (Patton 1976)[3] can serve as a guide for developing priorities for other areas. Six general categories of studies are necessary to provide natural resource managers with sound data for making decisions (fig. 2).



Figure 1.--Riparian habitat along East Verde River, Tonto National Forest, Arizona.

[1]Paper presented at the Symposium on Importance, Preservation, and Management of Riparian Habitats, Tucson, Ariz., July 9, 1977.

[2]Principal Wildlife Biologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, at the Station's Research Work Unit at Arizona State University, Tempe. Central headquarters is maintained at Fort Collins in cooperation with Colorado State University.

[3]Patton, David R. 1976. Habitat criteria development for southwestern wildlife. A problen analysis. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Tempe, Arizona. Unpubl. rep.

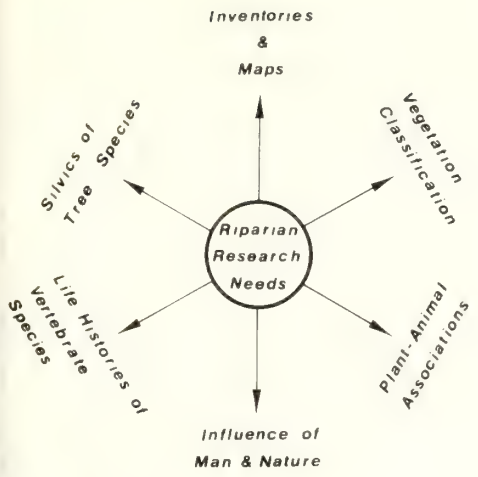


Figure 2.--Riparian Research Needs

These categories only provide an outline for research. Each researcher will have to determine his own priorities depending on the need for data at the local, state, or regional level. Most of the problems, however, can be placed into one of these groups. The research categories are not mutually exclusive, and can be dealt with using a team or multidisciplinary approach.

INVENTORIES AND MAPS

A map and inventory of the riparian resource are very much needed. Aldo Leopold always emphasized that these tools were basic to all management decisions. Preparation of maps and inventories may not be a researcher's job, but he can provide some of the necessary information. In the Southwest, the vegetation map by Brown et al. (1977a) is a major step in the inventory and mapping process. In addition, Brown et al. (1977b) prepared a stream map for Arizona that identifies areas where riparian vegetation should or could exist.

VEGETATION CLASSIFICATION

No comprehensive classification of riparian vegetation suitable either for research or management has been prepared for the Southwest. The hierarchical system proposed by Brown and Lowe (1974) as part of the Arizona Resource Inventory System (ARIS) is an important step in characterizing vegetation on a regional basis to the community and association level. Studies are needed to determine plant species composition and abundance for every identifiable successional stage for riparian vegetation, from low-elevation desert to high-elevation spruce-fir forests. An important part of the work should be to develop techniques for evaluating the riparian habitat's "state of health." Emphasis should be placed on studies of indicator plants.

PLANT-ANIMAL ASSOCIATIONS

Once successional stages have been determined, there is a need to identify animals that depend on a given stage or stages for their life requirements. Such studies do not have to be complex and can provide excellent field training for graduate students interested in the habitat approach to wildlife management.

Riparian habitats are oases in arid environments and support a great density and diversity of bird species. More is known about bird life in riparian vegetation than any other vertebrate group, but a check of the literature quickly shows a lack of detailed information on any animal. Some birds, such as the black hawk (Buteogallus anthracinus) and zone-tailed hawk (Buteo albonotatus), that inhabit or are semiriparian-dependent, are on state threatened lists and probably will become endangered unless research provides managers with information on their habitat requirements.

The needs of mammals that inhabit or are closely associated with riparian vegetation have not been well identified. Bats, squirrels and skunks often are seen in or near riparian vegetation, but their use of the type for food and cover is known only in general terms. Small rodents are probably the least understood and documented group of animals in the riparian habitat. These animals could be an important link in the food chain of threatened hawks.

Researchers have neglected amphibians and reptiles in favor of more economically important animals. Herps are not as esthetically pleasing to recreationists because of a lack of understanding of their ecological value. Yet, data on the two herp groups are necessary-to understand the complete riparian ecosystem.

Although fish are not restricted to streams with riparian vegetation, the presence or absence of streamside cover affects temperature which determines species composition. There probably is more detailed information available on game fish than on any single group influenced by riparian vegetation. Less data are available on threatened or endangered species. In addition many remote streams have not been surveyed or were insufficiently surveyed.

Invertebrates must be included in plant-animal relationship research. These animals are

an important source of energy in the food chain of riparian vertebrates. For this reason, there needs to be an understanding of the invertebrate populations associated with the hundreds of terrestrial and aquatic microhabitats in riparian vegetation.

INFLUENCE OF MAN AND NATURE

Grazing, pollution, recreation, flooding, and water reclamation projects all can influence plant and animal species composition and abundance. Managers need to know if desirable trees and shrubs can survive under any grazing system, or whether protection will be required during critical seasons to restore the balance between production and utilization.

Most natural systems can withstand some pollution, but overloads soon become toxic to both plants and animals. At that point it may be too late for recovery. Studies are needed to determine recovery rates associated with different amounts of pollutants and their chemical toxicity of the plant-animal complex. Recreational activities can cause pollution from human wastes and physical damage. Managers need information on carrying capacity to regulate access when overuse becomes a problem.

The riparian habitat must have water. In most of the West, demands for water lead to conflicts between human uses and needs and other uses and needs. Floods, caused by either man or nature, can be either beneficial or detrimental. Some riparian plants need occasional flooding to perpetuate the species. However, removal of large amounts of vegetation in watershed treatments may create conditions conducive to flooding that can destroy desirable plants. Minimum flows to maintain the riparian habitat as a viable biological system must be determined soon, or managers will not have the information they need to mitigate habitat losses from dam and reservoir projects.

SILVICS OF TREE SPECIES

Life history data on the important riparian deciduous tree species--sycamore, cottonwood, willow, ash, and walnut--are almost nonexistent. The lack of data on these species resulted from a research emphasis on species with direct economic value. Studies are needed to document site requirements for germination and sprouting of seedlings or suckers, effects of insects and fire, and techniques for artificial regeneration.

LIFE HISTORY OF VERTEBRATE SPECIES

Life history information provides biological data necessary for understanding each species' role in the ecosystem and the effects of man's activities. Because of the large number of vertebrates that live in or are influenced by the riparian habitat, the task of documenting all their relationships with the plant complex will be a difficult one. Species on the state and federal threatened and endangered lists should receive top priority. In many cases it may be possible to group species for study by common requirements or life forms.

USEFUL CONCEPTS

Two concepts may help to plan and initiate research in the riparian habitat. The first is establishing validation sites. A validation site is an area that represents a given vegetation condition or successional stage. It is permanently documented by maps and aerial photographs and used for long-term studies. In some areas, validation sites may need permanent exclosures for protection from grazing. By using validation sites, scientists of many different disciplines can work together on separate studies to solve common problems.

Roy Johnson discussed the second concept, "endangered habitat", earlier. Several years ago I found the same terminology useful for describing riparian vegetation in a wildlife problem analysis. These select words directed attention to a habitat containing endangered and other species that depend on a vegetation type that itself is in a precarious position. The concept of threatened and endangered habitat, when properly used, may increase the chances of getting funds for research for a variety of species, living in that habitat, that otherwise would not receive high priority.

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Riparian Habitat Symposium Closing Remarks[1]

M. J. Hassell[2]

I don't know about you folks, but I personally have found this symposium to be very interesting and enlightening.

My only regret is that Bill Hurst, the man I replaced as Regional Forester, was not here to participate. When he first came to the Southwestern Region, I was a staff assistant in the Range and Wildlife Division. The first time I remember hearing the word "riparian," Bill was remarking worriedly that there was something wrong with our sycamore and cottonwood stands. No trees, shrubs and forbs in the younger age classes were represented, and this was a worry to this keen-eyed forester.

Now I know the reason. Age class "poverty" has been the subject of many papers. But, when Bill Hurst was expressing concern; few, if any, had even recognized the problem. He deserves much credit for the fact we are here today.

Bill Morris, you made a good point which I agree with. Therefore, another reason this symposium has been so meaningful to me is personal and perhaps even selfish. Our Region of the Forest Service has been attempting to put out a policy statement on the riparian type. As competition for resources intensifies, we desperately need basic information that identifies the trade-offs of resource conflicts. I don't believe it is acceptable to jump up and down totally in the dark - we need more information to make better choices. The speakers today have supplied much of the needed information, and I, for one, am extremely grateful. It is my hope that you have been able to glean some helpful information from the discussions.

Steve Carothers set the stage for our concerns and our reasons for being at the symposium. Of course, the basic reason is that changes are taking place in riparian habitat, and these changes and their direction are significant.

The riparian type is a key type to many kinds of uses and species. Both Kel Fox and John Hubbard covered this well in their discussions on domestic livestock, wildlife and fish; humans, water source and recreation.

Earle Layser and Charlie Pase highlighted the fact that this valuable type is very limited and the need we have to classify it. The framework provided through classification would permit scientists and managers better communication about what the problems and possibilities are.

Dave Brown highpointed the need for inventory in the riparian type, and we were able to see some of the difficulty of getting this basic data.

The challenge is to understand the importance of the type for all the various uses, to exchange what is known, to research what is not known, and to finally reach workable adjustments and compromises.

We realize it has been difficult to digest all the information you have heard today. But, in case you missed a point or two, Director Herrick of the Rocky Mountain Station has volunteered to print these transactions. They should be available for all registrants at a later date.

On behalf of all the cosponsoring groups, we would like to thank you for making this symposium a success. If riparian habitat and its associated fauna receive the attention it has long deserved, we will all be the richer for this experience.

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[1]Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

[2]Regional Forester, U.S. Forest Service, Region 3, Albuquerque, New Mexico.

Contributed Papers

Classification of Riparian Vegetation[1]

William A. Dick-Peddie[2] and John P. Hubbard[3]

Abstract--Historically, little attention has been given to vegetation associated with water courses. The reasons for this neglect are reviewed. Today there is considerable interest in riparian vegetation and a classification system would be of value. A classification system is proposed for riparian vegetation of New Mexico.

INTRODUCTION

Vegetation growing along rivers, streams, arroyos, and drainages in general has seldom been separately classified as a unit.

Reasons For No Classification System

Apparently there have been a number of conditions contributing to this omission. One condition is that historically, vegetation occurring on open flats, rolling hills, and mountain slopes has been of far greater economic importance than the vegetation associated with water courses. As a consequence, these areas of grassland and forest have tended to monopolize the attention of researchers.

Another condition responsible for the lack of separate classifications is that the area occupied by drainage associated vegetation often constitutes a small fraction of the total area being considered. The scale frequently used for mapping (continent, region, state, etc.) makes the recognition of this vegetation impractical or impossible. This is particularly true in mountainous regions where due to steep slopes, the drainages are relatively narrow and the vegetation associated with these systems constitutes only a thin band bordering either side of the reach. In addition the reach may be at the bottom of a gorge, canyon, or arroyo gully. In the plains and rolling country of the midwest and east, vegetation which is associated with wide old meandering drainage systems (floodplains) may make up a considerable portion of the total vegetation. When it does, these areas have sometimes been classified and mapped. Kuchler's (1964) southern Floodplain Forest (113) and Northern Floodplains Forest (98) are examples of this situation.

A third condition which has undoubtedly provided resistance to classification is the apparent lack of sufficiently discreet boundaries to the species aggregations as one proceeds up or down a drainage. Complicating this strong continuum condition is the fact that most species which grow out in the open are also able to grow along drainages. These species may be associated with typical drainage species in aggregation which are highly varied in both diversities and densities making creation of vegetative units exceedingly difficult.

Need for a Classification System

During the last fifteen or twenty years some conditions which prevented or restricted the development of classification systems for drainage associated vegetation have changed or disappeared and new priorities have even created a demand for a classification system.

There has been a considerable increase in the economic importance of wildlife which has resulted in an increase of research activity associated with the vegetation which supports wildlife. Much of this wildlife habitat is along drainage systems. A vegetation classification system would be of value in the management of these habitats.

The public has become interested in safeguarding examples of its natural heritage and the resultant competition between preservation and economic development of sites, necessitates biotic inventories. Biotic inventories are facilitated by a workable classification system.

Increased demand for water has focused an inordinate amount of attention on drainage systems in western United States and particularly in the southwest. This attention has led to various studies of water salvage. A natural consequence

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of this intensive activity is an interest in the role of drainage associated vegetation and water use. For an extensive literature review of this activity see Horton (1973). A realistic vegetation classification would be valuable for this continuing research effort.

The following is quoted from Lowe and Brown (1973) because it incorporates some of what we have said and indicates why we should be concerned about this type of vegetation.

> "The riparian communities are not shown on the color map. In total they comprise a limited geographic area that is entirely disproportionate to their landscape importance and recreational value and their immense biological interest."

> "It should not go unnoticed that in Arizona these riparian woodlands and streams forests have been rapidly dwindling just as the water table has been rapidly lowering, and our broadleaf trees are now the native phreatophytes of the water users. With present plans for increasing dams, flood control, water salvage, water forests are now truly endangered. Unless those concerned with projects such as the above do not quickly reasses their commitments, it will not be long before our riparian forests are destroyed forever in Arizona. They cannot be replaced."

Because of the changed and new conditions just explained, it is our opinion that a classification system for drainage associated vegetation is timely and highly desirable. We are also of the opinion that such a system is feasible.

TERMINOLOGY

Some terms used when discussing and describing this type of vegetation need clarification because their use has not always been consistent. In our view the following definitions are the most consistent and useful for these terms.

Riparian

Riparian - associated with water courses. Riparian may refer to vegetation associated with large rivers or with small, even intermittent drainages such as arroyos.

Phreatophytes

Phreatophytes - plants whose roots are growing in the water table or its capillary fring during a major portion of the growing season. Riparian vegetation may or may not include plants which are growing as preatophytes. Horton and Campbell (1974) have used riparian for situations along water courses where conditions are not suitable for phreatophytes. This use of riparian and phreatophytic as conditions which are mutually exclusive is a restrictive use and it can be confusing.

Bosque

Bosque - a stand of riparian vegetation including plants which are growing as phreatophytes. Consequently, the term bosque is usually limited to stands along major rivers or floodplains. Bosque is not as common a term as are riparian and phreatophyte. Bosque has a historical use in the southwest and has a different meaning here than in Mexico where it usually means merely forest, woods, or grove.

Bosques may vary from gallery forest-like stands of cottonwood *(Populus fremontii)* with their associated shrubs to impenetrable thickets which may include combinations or pure stands of such plants as screwbean *(Prosopis pubescens)* mesquite *(Prosopis glandulosa)*, seepwillow *(Baccharis glutinosa)*, saltcedar *(Tamarix spp.)*, arrowweed *(Pluchea sericea)*, and various species of willow *(Salix spp.)*.

Obligate Riparian Species

Obligate Riparian Species - species restricted to riparian or riparian-like situations. Riparian-like situations are those typlified by areas receiving large amounts of run-off water from surfaces with zero infiltration such as from the boulders of a talus slope or when the local topography creates an area of catchment which slows run-off sufficiently to allow greater infiltration than that of surrounding areas on the slope. We are aware that the term "obligate" implies a restrictive occurrence which has not been definitely ascertained for most of the species so designated However, the term serves to segregate the species which may occur in riparian situations but are more commonly found elsewhere.

Facultative Riparian Species

Facultative Riparian Species - species other than "obligates" found in a riparian situation. Some riparian habitats are virtually restricted to obligate species because of poor aeration and/or high slainity. This is often the case along large river systems where there may be high water tables and phreatophytic conditions However, in montane situations where there is good drainage or where running water is intermittent or sporadic (arroyos), any species including obligate species can be expected. These facultative species can usually be found out in the open at higher elevations. This is a result of the increased water availability in

riparian situations. This increased water availability is due to the additional surface or ground water and/or the reduced evapotranspiration rates (canyon effect) associated with riparian situations.

RIPARIAN CLASSIFICATION

Recent Research Related to Classification

During the past two decades there has been considerable interest in riparian vegetation. Particularly in the west (Horton 1973). This interest has slowly been heading toward attempts at classification.

In the southwest, the biologist who has perhaps led the way toward recognizing the importance and character of riparian biotas is Charles H. Lowe, Jr. For example, Lowe (1961) defines riparian associations - or communities - and discusses various aspects of them in his treatment of the Sub-Mogollion region of New Mexico, Arizona, Chihuahua, and Sonora. He defines the associations as those occurring "in or adjacent to drainage ways and/or their floodplains and which are further characterized by different species and/or life-forms than those of the immediately surrounding non-riparian climax." He emphasizes that "it is incorrect to regard this biotic formation as merely a temporary, unstable seral community," as "it is an evolutionary entity with an enduring stability equivalent to that of the landscape drainageways which form its physical habitat."

In recent years the pronouncements of Lowe have underlain an increasing concern and interest among biologists and others in riparian associations and their biotas. For example, several studies (e.g. Campbell and Dick-Peddie, 1964; Campbell and Green, 1968; Freeman and Dick-Peddie, 1970; Campbell, 1974) have focused directly on riparian plant communities, while others have related such communities to their use by such elements as birds (e.g. Hubbard, 1972; Carothers and Johnson, 1973; Schmitt, 1976). Even earlier papers were published in ichthyology (e.g. Miller, 1961) touching on the importance of riparian habitats to native fishes, but in general these views have been little appreciated by biologists until recently.

The awakening among biologists as to the importance of riparian biotas has also sparked increasing study, as indicated above. Initial studies have been valuable but limited to date, and a great deal remains to be learned. One thing that is apparent however, is the fact that a great deal of complexity exists in riparian biotas. Not the least item among this complexity is the matter of sorting riparian vegetation into a workable and valid system of classification. Attempts have already been made to achieve this classification, but to date none of these is entirely satisfactory.

Inclusion of Riparian Elements In Vegetation Classification Systems

Lowe and David E. Brown have collaborated in developing a vegetation classification system for the southwest, to include riparian types. In their latest endeavor, for example, Brown and Lowe (1974) recognized twelve different riparian communities. Following are two examples:

Forest Formation

- Boreal Forest
  - Sub-Alpine Conifer Forest
    - Bristlecone-Limber Pine Communities
    - Spruce-Alpine Fir Communities
- Temperate Forest
  - Montane Conifer Forest
    - Douglas-fir - White Fir Communities
    - Pine Communities
  - Relict Conifer Forest
    - Cypress postclimax Communities
  - Riparian Diciduous Forest
    - Mixed Broadleaf Communities
    - Cottonwood-Willow Communities

Woodland Formation

- Boreal Woodland
  - Sub-Alpine Riparian Woodland
    - Willow Communities
- Temperate Woodland
  - Rocky Mountain Conifer Woodland
    - Pinyon-Juniper Communities
  - Madrean Evergreen Woodland
    - Mexican Oak-Pine Communities
    - Encinal (Oak) Communities
  - California Evergreen Woodland
    - Oak-Pine Communities
    - Encinal (Oak) Communities
- Subtropical Woodland
  - Riparian Deciduous Woodland
    - Mesquite Bosque Communities
    - Tamarisk disclimax Communities

In a preliminary classification of New Mexican vegetation, Moir (1975)[1] included

[1]Moir, W.H. 1975. Vegetation Classification System for use in New Mexico. Developed for the New Mexico Natural Areas Problem, UNBUB.

riparian elements as parts of his major categories as follows:

Coniferous Forest Association
  Blue Spruce Series
    Blue Spruce/Grass Streamside Association
      Aspen Community
      Willow-Alder Community

Deciduous (Riparian) Woodland Formation
  Fremont Cottonwood Bosque

  Arizona Sycamore Series
    Arizona Sycamore/Fremont Cottonwood Association
    Arizona Sycamore/Arizona White Oak Association
    Arizona Walnut Series
    Bigtooth Maple Series
    Other Series

Forest Steppe (Mountain Grassland) Formation
  Wet Meadow Series
    Mesic Forb Community
    Sedge-Grass Community
    Willow-Sedge Community

Pase and Layser (1977)[4] have further refined ghe Brown and Lowe system in a tentative classification. Following are two examples:

Temperate Riparian Deciduous Forest Biome
  Mixed Broadleaf Series
    Mixed Broadleaf Associations
    Acer negundo Associations
    Alnus oblongifolia Associations
    Platanus wrightii Associations
    Fraxinus velutina Associations
    Juglans major Associations

  Cottonwood-willow Series
    Populus fremontii - mixed broadleaf Associations
    Populus fremontii Associations
    Salix bonplandiana Associations
    Populus fremontii - *Salix goodingii* Associations

Subtropical Riparian Deciduous Woodland Biome
  Mesquite bosque series
    Prosopis juliflora Associations
    Prosopis juliflora - mixed narrowleaf *(Tamarix, Chilopsis, Celtis)* Associations

[4]Pase, C.P. and Earl F. Layser. 1977. Classification of Riparian Habitats. Paper presented at Riparian Habitat Symposium, Tucson, Arizona.

A Riparian Classification System

The previous examples of the inclusion of riparian categories in classification are all worthy and valid. However, in light of its importance and the fact that it represents an unbroken continuum somewhat independent (particularly in the case of obligate species) of the surrounding vegetation, it would appear that riparian vegetation might well be treated as an independent vegetative unit. By concentrating upon obligate species, the seemingly bewildering array of combinations, is greatly reduced. Research on correlations of obligate species with such variables as surface and subsurface hydrology; canyon or valley cross sections and dimensions; and reach elevations and exposures should render more predictable the presently unpredictable occurrences of many obligate species. Such occurrence predictability would enhance the validity of a classification system.

Selection of Obligate Riparian Species

Some of the obligate riparian species found in one area have counterparts in their genera as obligates in other areas. For example some dominant floodplain genera in eastern United States are *Acer* (maple), *Fraxinus* (ash), *Platanus* (sycamore), *Populus* (cottonwood), *Juglans* (walnut), and *Salix* (willow). These same genera include major obligate riparian species in the southwest. Other species are obligate riparian species in the southwest but their counterparts in the same genera are merely facultatives elsewhere. Some examples of these genera are *Betula* (birch), *Celtis* (hackberry), and *Cornus* (dogwood).

Even though the obligate nature of the species so designated has not been scientifically established it is not difficult to arrive at a list of these species for any given area. For example, following is a list of woody and grass or grass-like obligate riparian species in New Mexico. This list is undoubtedly incomplete and some specialists may take exception to a few of the included items. The list is the result of lists compiled by the authors and a list compiled by Dr. Hal McKay while working as a consultant for the New Mexico Heritage Program. Concensus on a list of obligate forbs is equally easy to compile but due to the large number of forb species a list of forbs is not included in this paper.

Major Obligate Riparian Plants
Found in New Mexico

*Exotic (introduced)

Trees

Acer negundo	Box elder
Alnus oblongifolia	New Mexican alder
Betula fontinalis	Birch
Celtis reticulata	Desert hackberry
Fraxinus spp.	Velvet ash
Juglans major	Walnut, Nogal
Juglans microcarpa	Little walnut
Morus microphylla	Mulberry
Picea pungens	Blue spruce
Platanus wrightii	Sycamore
Populus acuminata	
Populus angustifolia	Narrow-leaf cottonwood
Populus fremontii	Fremont cottonwood
Populus sargentii	Plains cottonwood
Prunus virginiana	Common chokecherry
Salix gooddingii	Southwestern black willow
Sapindus saponaria	Soapberry

Shrub-Trees

Acer grandidentatum	Bigtooth maple
Alnus tenuifolia	Thin-leaf alder
Amelanchier spp.	Service-berry
Amorpha fruticosa	False indigo
Cercis occidentalis	Redbud
Chilopsis linearis	Desert willow
Crataegus spp.	Hawthorn
**Elaegnus angustifolia*	Russian olive
Prosopis glandulosa	Mesquite
Ptelea angustifolia	Hop-tree
**Tamarix spp.*	Salt cedar

Shrubs

Acacia greggii	Catclaw
Allenrolfea occidentalis	Iodine bush
Apocynum spp.	Dogbane
Baccharis emoryi	Baccharis
Baccharis glutinosa	Seep willow
Baccharis sarothroides	Desert broom
Brickella californica	Brickel bush
Brickella laciniata	Brickel bush
Chrysothamnus nauseosus	
Var. graveolens	Rabbit-brush
Var. bigelovii	Rabbit-brush
Chrysothamnus pulchellus	Rabbit-brush
Cornus stolonifera	Red-osier dogwood
Fallugia paradoxa	Apache-plume
Forestiera neomexicana	New Mexico Olive
Hymenoclea monogyra	Burro weed
Lonicera involucrata	Inkverry
Lycium torreyi	Wolfberry
Philadelphus microphyllus	Mock orange
Pluchea sericia	Arrow weed
Rhamnus betulaefolia	Birchleaf buckthorn
Rhus microphylla	Little-leaf sumac
Salix spp.	Willow
Sarcobatus vermiculatus	Greasewood
Shepherdia argentea	Buffalo-berry

Grasses & Grass-like

**Alopecurus spp.*	Fox-tail
**Arundo donax*	Giant-reed
Bulbostylis spp.	
Carex spp.	Sedge
**Catabrosa aquatica*	Brook grass
cyperus spp.	Flat-sedge
Distichlis stricta	Salt grass
Eleocharis spp.	Spike-rush
Equisetum spp.	Horsetail
Fimbristylis spp.	
Glyceria spp.	Manna grass
**Hordeum hystrix*	Barley
**Hordeum jubatum*	Barley
Juncus spp.	Rush
**Leersia oryzoides*	Cut grass
Luzula spp.	Wood-rush
**Phragmites communis*	Reed
Polypogon spp.	Rabbitfoot
Scirpus spp.	Bulrush
Typha latifolia	Cat-tail

Potential Classification of New Mexican Riparian Vegetation

We present a potential classification of riparian vegetation in New Mexico. This is done to illustrate the validity of a system based upon obligate riparian species and the major topographic features which dictate their presence. The classification does not rely upon categories such as Boreal, Temperate, Subtropical, Forest, Woodland, and Scrubland which were developed primarily for non-riparian vegetation.

380 RIPARIAN FORMATION

381 Alpine Sub-Formation
381.1 Forb Series
381.11 Rush Association
381.12 Spike Rush Association
381.13 Sedge Association

Montane Sub-Formation
Willow-Alder Series
Willow Association
Alder Association
Willow-Alder Association

Blue Spruce Series
Blue Spruce Association

Mixed Dedicuous Series
Willow-Dogwood Association
Alder-Willow Association
Boxelder-Ash-Walnut Association
Sycamore Association

Hackberry Association

Arroyo-Floodplain Sub-Formation
Arroyo Scrub Series
Greasewood Association
Rabbitbrush Association
Desert Willow-Brickelbush Association
Burroweed-Four-Winged Saltbush Association

Floodplain (Bosque) Series
Cottonwood Association
Cottonwood-Willow Association
Mesquite Association
Arrowweed-Seep-willow Association
Saltcedar Association
Mixed Bosque Association

It would not be difficult to incorporate this riparian classification into existing systems. We have included digits for the first series as an illustration of how this classification could utilize the Brown and Lowe system. We have used the major unit terminology of Formation, sub-Formation Series, and Association to illustrate the applicability of this proposed classification to the system being developed by the Forest Service.

The proposed classification is intentionally labelled "potential." Some units may not be valid or have utility when applied in the field. Possibly, some units should be raised or lowered in the hierarchy. There will undoubtedly be additions and possibly a need for deletions. Continued research and use of the classification should serve to remove any such errors.

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Fishes Inhabiting the Rio Grande, Texas and Mexico, Between El Paso and the Pecos Confluence[1]

by Clark Hubbs[2], Robert Rush Miller[3], Robert J. Edwards[2], Kenneth W. Thompson[2], Edie Marsh[2], Gary P. Garrett[2], Gary L. Powell[4], D. J. Morris[5], and Robert W. Zerr[5]

Abstract --The fishes of the middle part of the Rio Grande can be divided into three faunal assemblages: The saline Rio Grande fauna (made up of widely distributed and salt tolerant species) upstream from the Conchos confluence; the Rio Conchos-Rio Grande fauna (mostly south Texas and Mexican species) in the Rio Grande between the Conchos and Pecos; the tributary creek fauna (Chihuahuan species plus some derivatives) that depend on tributary creeks for all or part of their life history stages. Endangered species are found in the last assemblage but two presumed endangered species (Notropis simus and Scaphirhynchus platyrynchus) seem to have been eliminated already.

INTRODUCTION

The fishes of the Rio Grande (Belcher, 1975: fig. 3) have been intermittently studied for the past 130 years. Reasonably extensive reports exist for Colorado (Beckman, 1952), New Mexico (Koster, 1957), and the Rio Grande downstream from its confluence with the Pecos River (Trevino-Robinson, 1959). No comparable summarization exists for the intervening segment, although Miller (1977) treated the Mexican part of the middle Rio Grande basin. Proposals to channelize about 300 kilometers of the river and to designate another 200 kilometers as a wild river underscored the absence of a summarization of the fish fauna. The bulk of this paper is a report on fishes collected on two recent visits to the Rio Grande in the two project areas. We also include a summarization of a large number of collections made from the Rio Grande in Big Bend National Park between 1954 and 1976.

The Rio Grande "enters" Texas as a small stream most or all of which is diverted to irrigate fields south and east of El Paso. Commonly, the stream is dry over much of the distance between El Paso and Ft. Hancock. Southeast of this town the valley narrows and the ground water surfaces to form a salty stream. The river remains small for the next 300 km until it "receives" the Rio Conchos. Small volumes of water are added by small salt laden springs (such as Indian Hot Springs) and fresh tributary creeks (such as Capote Creek). These increases are commonly exceeded by losses from evaporation or irrigation diversions. Drastic increases in flow periodically follow intense desert rains. These torrents soon subside and the Rio Grande again becomes a small, sometimes intermittent stream. This pattern is of long duration as Emory (1859) reported periodic dry stream beds and occasional severe flooding and Thomas (1963) reported high salinities in the Rio Grande in 1936. This reach of the river has been extensively impacted by human activities. Much of the flow (and most of the low saline water) is diverted at or north of El Paso. The northwestern 150 kilometers have been leveed and channelized. A 16 kilometer segment around the Conchos confluence has also

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been leveed and channelized. The intervening 300 kilometers has been proposed for channel "rectification" and is extensively leveed already.

Much of the flow of the Rio Grande east of the Conchos is dependent upon that "tributary". Historically, the contribution of the Conchos has been considerably greater than that of the Rio Grande above the confluence and that difference has been magnified by the Rio Grande diversions upstream. Present flow rates depend chiefly on releases from Luis L. León Reservoir; at the time of our visit on 18 March, 1977, the Conchos flow was nearly 2 orders of magnitude greater than that of the Rio Grande. Strangely, the man-made conjunction has the Conchos entering at a right angle; in effect a forced right angle turn of the huge stream where it enters the small stream. Between the end of its rectified channel below Presidio and the upper part of Amistad Reservoir (just upstream from the Pecos confluence), the Rio Grande has not been substantially impacted by human activities. The major items are the stream measurement weirs just below Alamito Creek and just above Amistad Reservoir, river fords at Stillwater Crossing and Boquillas, and a bridge near Stillwater Crossing. Other impacts are indirect such as minor irrigation diversions, overgrazing, exotic plants and fishes, pesticides washed from nearby fields, leaching from mine tailings, etc. Much of this distance is little disturbed and one can see the diverse geology and magnificent land formations.

COLLECTION SITES

Most of the newly reported locality records are based on two collecting trips, 14-18 March and 3-7 April, 1977. Collections were concentrated in the channelization and wild river segments, respectively. Previously, only one sample had been obtained from each of those reaches. The 1977 and previous (1954) locations are plotted on figures 1 and 2. The bulk of the 1954 (and subsequent) Rio Grande collections were from the Big Bend National Park and have been reported in Hubbs (1958), Hubbs and Wauer (1973) and Hubbs and Williams (in press).

RESULTS

The 15 collections from the Rio Grande west of the influence of the irrigation water from the Rio Conchos that enters the Rio Grande between Stations 15 and 16 contain 11 fish species (Table 1). The redundant nature of these samples is reflected by the presence of 7 fishes (Dorosoma cepedianum, Cyprinus carpio, Notropis lutrensis, Carpiodes carpio, Ictalurus punctatus, Gambusia affinis, and Lepomis cyanellus) in 9 or more collections.

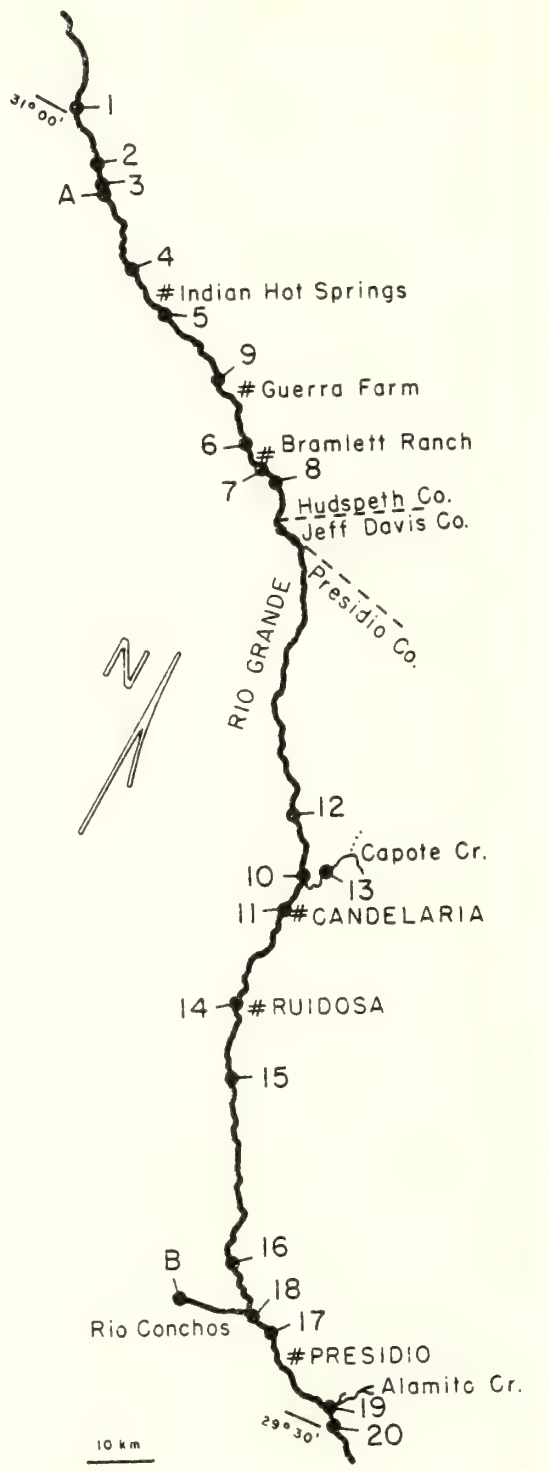


Figure 1.--Location of collection stations in the Rio Grande from and adjacent to the proposed channelization.

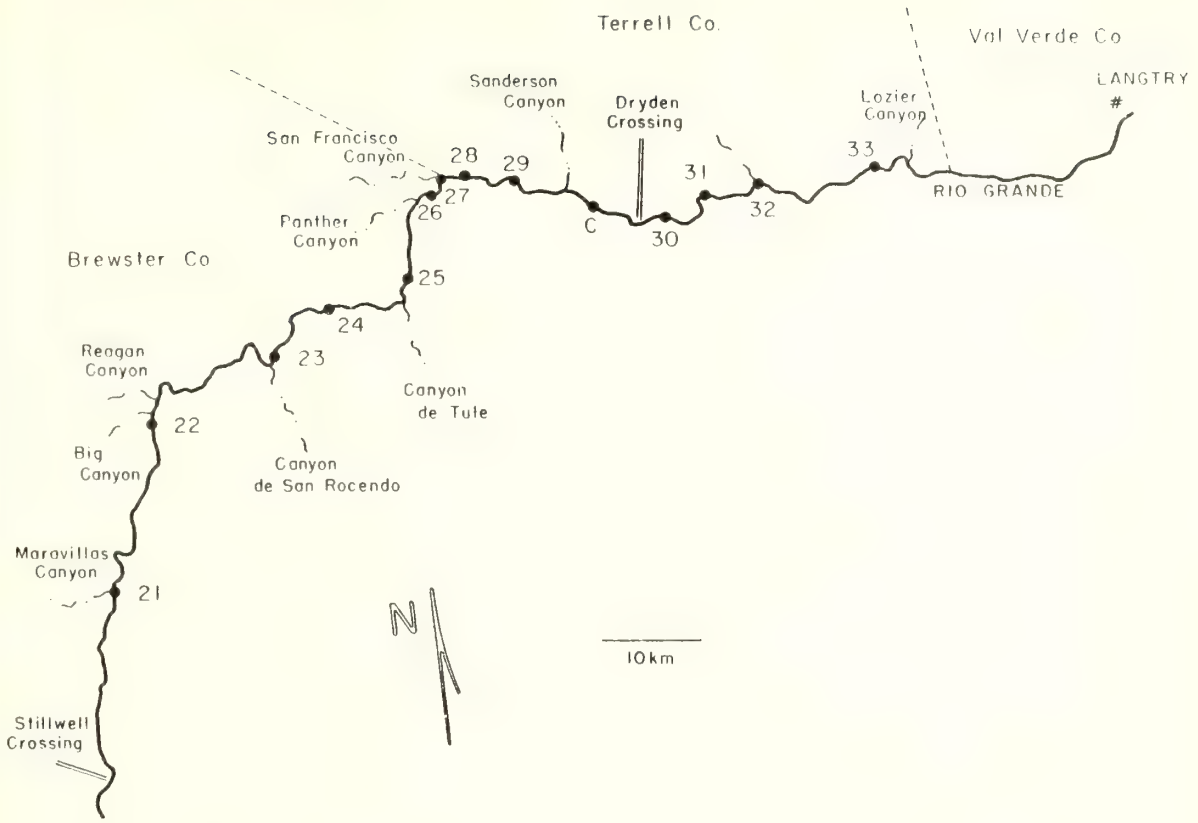


Figure 2.--Location of collection stations in the Lower Canyons of the Rio Grande.

Their widespread abundance suggests that they would be expected anywhere in this stream segment. The second listed species (Cyprinus carpio) is an exotic but the others are all widely distributed native fishes. Two of the other four species (Lepomis megalotis and Morone chrysops) were collected at widely separated sites. The former was found at very brushy sites. It is likely that this species can be obtained wherever those conditions prevail. The latter (undoubtedly, derived from fishes stocked near Del Rio) is an open-water top carnivore. This fish would be expected to be sparsely distributed because of dependence upon a complex food chain and consequently high primary productivity per fish. In a similar way, a large fish like Ictalurus furcatus would be expected to be rare in a small stream like the Rio Grande in this reach. The last species Pimephales vigilax, has not previously been taken east of Val Verde Co. As this fish is commonly used as a bait minnow, it is likely that the samples obtained are descendants from escaped bait.

The six collections from the vicinity of Presidio (16B on Table 1) contain 20 species; 11 were not taken upstream but 2 from there were absent. We expect that increased effort would have produced an Ictalurus punctatus, but that Pimephales vigilax is not present. Nine of the additional 11 species, Astyanax mexicanus (as A. fasciatus), Hybopsis aestivalis, Notropis chihuahua, Notropis braytoni, Notropis jemezanus, Pimephales promelas, Campostoma ornatum, Pylodictis olivaris, and Lepomis macrochirus, were reported from the Big Bend region by Hubbs (1958). One exception, Cyprinodon eximius has subsequently been reported from Terlingua creek by Miller (1977). The other, Menidia beryllina, is undoubtedly derived from descendants of bait-released stocks now abundant in Amistad Reservoir. We expect that Menidia (a euryhaline species) will soon spread and become abundant in the saline Rio Grande waters upstream from the Conchos confluence.

The distinct difference between the Rio Grande fishes on either side of the Conchos confluence is reflected by similar differences between the fishes inhabiting the tributary creeks, Capote and Alamito (stations 13 and 19, respectively).

Table 1.--Numbers of fishes collected from the Rio Grande from and adjacent to the proposed channelization between Presidio and El Paso

Species	Stations																				
	A	1	2	3	4	5	9	6	7	8	12	10	13	11	14	15	16	18	17	19	20	B
Dorosoma cepedianum		14	108	133	1	23	3		6		3	43		1	21	14	159	18	4		4	10
Astyanax mexicanus																				1		8
Cyprinus carpio	2	58	26	28	1	29	5	50	16	1	14	125	6	65	86	28	57	2		1	1	7
Hybopsis aestivalis																			17		13	4
Notropis chihuahua																			1	3		
Notropis braytoni																				1	1	44
Notropis lutrensis	74	11	13	83	130	242	66		49	85	55	335	118	40	11	65	54	50	354	166	63	36
Notropis jemezanus																						22
Pimephales vigilax			2	1		1																
Pimephales promelas																				1		3
Campostoma ornatum																				262	16	
Carpiodes carpio	x	1	2			26			2	2		74		2			7	1				3
Ictalurus punctatus		1	1		1		1		1	5	3	1		4								
Ictalurus furcatus							1												1		2	5
Pylodictis olivaris																					1	1
Cyprinodon eximius																				13	1	
Gambusia affinis	18	1		1		9		7	1	61		1		7	5	122	57			78	28	14
Menidia beryllina																	2	4	4	10	1	
Morone chrysops		1		2	1							1		1								
Lepomis cyanellus	2	4		2	4	8	2	11	7	2	4	23		29	38	105	168	2		11	4	3
Lepomis megalotis	2								1	2				2			1					
Lepomis macrochirus																		1				
H'		1.7	1.3	1.5	0.4	1.5	0.9	1.1	1.8	1.4	1.4	1.7	0.3	2.1	1.8	2.0	2.2	1.6	0.5	1.6	2.3	
% Introduced		65	18	12	1	9	6	74	19	1	18	26	5	44	53	8	12	8	1	2	2	
Fish/seine hour		46	101	119	92	193	156	136	166	351	79	316	248	151	161	445	500	78	381	527	133	

Table 2--List of fishes collected from the Lower Canyons of the Rio Grande.

Species	Stations													
	21	22	23	24	25	26	27	28	29	30	31	32	33	C
Lepisosteus osseus			1			1			2	1		1		1
Dorosoma cepedianum	15				3	21	1	2	7	11	3	5	1	
Cycleptus elongatus	108	2	15	1	6	7	2			5	4	19	1	
Carpiodes carpio	5	1		1	1		1	2		1	2	8		31
Ictiobus bubalus	1											1		1
Astyanax mexicanus						1						33		1
Cyprinus carpio	3						1							1
Rhynichthys cataractae	188	182	209	92	87	77	47	184	141	191	168	850	167	
Hybopsis aestivalis	4	13	36	8	6	7	4	6	3	3	11	9	9	2
Pimephales promelas			1							1				
Notropis chihuahua	1													
Notropis jemezanus	3	5	7	4	20	19	3	3	48	5	16	6	12	11
Notropis lutrensis	6	1	19	1	5	112	4	6	2	12	29	37		1
Notropis braytoni		2	11	3	15	9	4	19	6		6	10	3	25
Ictalurus punctatus		1	7	2	2		3		2		2	1	7	2
Ictalurus furcatus		5	13	10	6		4	3	8	1	4		2	69
Pylodictus olivaris		1	4		2						3	1	2	6
Fundulus kansae	2													
Gambusia affinis	3		4			4	4					1		
Menidia beryllina				2		1			1			2		
Micropterus salmoides				1	1							4		
Lepomis cyanellus	1													
Lepomis macrochirus	1		1											

hemical and physical conditions in the two reeks are reasonably similar - Capote s slightly smaller and has been reported dry ear the mouth. We attribute the fish faunal ifferences to the impact of seasonal migrations into the Rio Grande as reported for Teringua Creek by Hubbs and Wauer (1973). Those alty Rio Grande waters at the mouth of Capote reek may exclude the typical Rio Grande tributary creek fauna from any upstream tributary. egardless of the cause, these fishes were not ound in Capote Creek. We looked carefully for ishes in the waters of Indian Hot Springs to etermine if an endemic fauna were there. These arm, salt-laden springs were fishless. We did ote Gambusia affinis was concentrated in the arm outflow waters emptying into the colder io Grande waters during our March visit.

The faunistic difference between the ishes of the two segments is of long duration. he 1954 samples (A and B) are well representative of the faunal units found in 1977 samples.

The 13 collections from the Lower Rio rande Canyons contained 23 species (Table 2). hirteen (Dorosoma cepedianum, Carpiodes carpio, styanax mexicanus, Hybopsis aestivalis, Pimehales promelas, Notropis chihuahua, Notropis emezanus, Notropis lutrensis, Notropis brayoni, Ictalurus furcatus, Pylodicitis olivaris, ambusia affinis, and Lepomis macrochirus) ere found in the collections near Presidio nd reported from the Rio Grande in Big Bend ational Park (Hubbs, 1958). The absence of ycleptus elongatus and Rhinichthys catarac-ae from the upstream stations is likely to e a seasonal artifact because both have been eported from the Rio Conchos. Both species re also absent in the August 1954 collection C). All of the Cycleptus collected downtream were young of the year. Similarly, he bulk of the Rhinichthys were young. It s unlikely that adult Cycleptus would be ollected with the seines used in such high ater (and none were). Samples taken near the outh of Tornillo Creek in April commonly have any young Cycleptus but no adults are in colections from that spot. Similarly, Rhinichthys re likely to be most abundant just after the reeding season. Our station 20 (Rio Grande ast east of the mouth of Alamito Creek) included one fish tentatively identified as a hinichthys that escaped prior to being preerved. Rhinichthys abundance in the area is upported by its presence in a collection from he Rio Grande just upstream from Mariscal Canyon n Big Bend National Park. Specimens have also een taken from the Conchos system in Chihuahua. he absence of Lepisosteus osseus, Ictiobus ubalus and Micropterus salmoides in the colections near Presidio is likely to be a sampling artifact. The high-water flows made it ery difficult to sample deep-water environments commonly occupied by these (especially Ictiobus and Micropterus) and our downstream samples were sufficiently infrequent that chance occurrence in the Presidio samples is likely. Two species (Menidia beryllina and Lepomis cyanellus) were collected near Presidio but not reported from Big Bend National Park by Hubbs (1958). It is unlikely that the former existed in the region before 1960 as Tilton and White (1964) showed that this fish was then just being distributed across Texas. Hubbs and Echelle (1972), documented a similar and recent spread of this fish in the Pecos Basin. Lepomis cyanellus is now known from Big Bend National Park (Hubbs and Williams, in press), supporting Hubbs' (1958) prediction that it existed within the park. Similar to Menidia audens, Fundulus kansae has recently been introduced into the region. Its introduction and subsequent spread was reported by Hubbs and Wauer (1973). The fish from the Rio Grande at the mouth of Maravillas Cr. surely reflects an additional spread. We herein also report the presence of Fundulus kansae in McKinney Spring in Big Bend National Park. It is likely that the specimens of Micropterus salmoides reflect a modest population of indigenous fishes that can serve as a recreational resource. We expect that largemouth bass occur throughout the Rio Grande east of the Conchos confluence (and also in much of the Conchos system).

The 23 species extensively overlap those reported from the Big Bend by Hubbs (1958) who recorded 7 additional fishes. Four of them, [Dionda episcopa, Gambusia gaigei, Lepomis (=Chaenobryttus) gulosus, and Lepomis microlophus] were recorded as inhabiting small clear tributaries and would be rare or absent in the river proper. Moxostoma congestum was subsequently reported from Tornillo Cr. by Hubbs and Wauer (1973). Three fishes, Anguilla rostrata, Hybognathus placitus, and Aplodinotus grunniens) were reported from Big Bend by Hubbs (1958), but not obtained in the 1977 samples. The first is catadromous and upstream migrants would be unlikely to pass Falcon Dam (much less Amistad); samples have not been obtained since Falcon was filled. The other two would be expected to occur in the area. Aplodinotus could easily have been overlooked but the absence of Hybognathus is inexplicable.

DISCUSSION

The fishes inhabiting the Rio Grande in west Texas can be placed in three faunal assemblages: Saline Rio Grande fauna, Rio Conchos-Rio Grande fauna, Tributary Creek fauna.

The Saline Rio Grande Faunal assemblage is dominated by four wide spread species, Dorosoma cepedianum, Cyprinus carpio, Notropis

lutrensis, and Lepomis cyanellus. The limited diversity (Shannon H' values are generally well below 2) seems to be due to harsh conditions - salinity and periodic interrupted stream flows. The latter may be most critical as the fish present are ones expected in pools in west Texas streams. Our repeated efforts in riffles were generally unproductive. This assemblage has been impacted by human activities. Certainly the three exotics (Cyprinus, Morone, Pimephales) must have some impact. It is likely that Cyprinus has depressed Carpiodes abundance but the impact of Morone and Pimephales is difficult to assess, and the absence of prior studies makes any conclusions conjectural.

The Rio Conchos - Rio Grande faunal assemblage is made up of those species living in the Rio Grande and not dependent upon tributary creeks for a part of their life history. The abundance of these fishes is not correlated with the presence of tributary flows. Typical fishes of this assemblage are Notropis jemezanus, N. lutrensis, N. braytoni, Rhinichthys cataractae, Hybopsis aestivalis, Ictalurus punctatus, Ictalurus furcatus, Pylodictis olivaris, Dorosoma cepedianum, Cycleptus elongatus, and Carpiodes carpio. Seven other fishes (Lepisosteus osseus, Ictiobus bubalus, Pimephales promelas, Menidia beryllina, Micropterus salmoides, Aplodinotus grunniens, and Hybognathus nuchalis) are reasonably abundant in the Rio Conchos-Rio Grande faunal assemblage.

Only one (Menidia beryllina) of those 18 species is introduced. Its impact is not yet fully assessed as its entry into the region is so recent that its abundance may be in a growth phase. It is not likely that this quiet water euryhaline form will become excessively abundant in the fresh-flowing waters of the Rio Grande. Rhinichthys cataractae is not only a prominent member of this faunal assemblage, it also seems to be absent or very scarce in adjacent areas. This population is isolated from other stocks by the saline and frequently dry Rio Grande upstream from Presidio. It is likely that it represents a race adapted to deep canyons with relatively warm water. Essentially, a collection from Texas with numerous Rhinichthys and/or Cycleptus is likely to be from the Rio Grande between Presidio and Amistad Reservoir. The Rio Conchos - Rio Grande faunal assemblage will often be supplemented by representatives from the tributary creek faunal assemblage.

Two fishes (Scaphirhynchus platyrynchus and Notropis simus) may once have inhabited the Rio Conchos - Rio Grande faunal assemblage. Scaphirhynchus was reported from the Rio Grande near Albuquerque by Cope and Yarrow (1875). We have obtained hearsay reports of a sturgeon from near Dryden Crossing (and also from Mexican tributaries in Coahuila) that support the former occurrence of shovelnose sturgeon in the river. Notropis simus has been recorded from the Rio Grande in New Mexico and downstream from Del Rio but the collections preceded or were at a similar time interval as the first collections from our study area. We doubt that Notropis simus now lives in the Lower Canyons of the Rio Grande and suggest that work to ascertain if it still exists concentrate on the lower Rio Conchos. We have no suggestions as to the conditions that may have led to the extinction or substantial decline of these two fishes that once were part of this faunal assemblage. Both species are commonly found on listings of endangered species and N. simus may be extinct in U.S. waters. Its absence in Trevino-Robinson's collections is particularly alarming as most Texas records are from that stream segment. The New Mexico records are from the Rio Grande in areas that now have reduced flow or are dry.

The tributary creek faunal assemblage is made up of a group of fishes that spends all or a substantial fraction of their time in the small tributaries. Three species (Notropis lutrensis, Pimephales promelas, Notropis braytoni) may occur in the creeks or Rio Grande. Except for the first, they are seldom found far from the creek mouth. Three (Moxostoma congestum Carpiodes carpio, Cycleptus elongatus) are creek inhabitants only as young and the adults may be found with equal abundance elsewhere in the Rio Grande. Eleven species (Cyprinodon eximius, Campostoma ornatum, Notropis chihuahua, Fundulus kansae, Astyanax mexicanus, Gambusia affinis and the sunfishes, Lepomis gulosus, cyanellus, microlophus, macrochirus, and megalotis) are most commonly collected in creeks but have been found in the Rio Grande. The first six are listed by relative frequency of creek vs. river abundance. Hubbs and Wauer (1973) had reported that this assemblage moved out of the creeks seasonally but our 1977 samples of the first two are the first demonstratio of fish that must have moved into the river. Samples of the five sunfishes are sufficiently infrequent that definite patterns are difficult to ascertain. Two species (Gambusia gaigei, Dionda episcopa) are limited to the tributary waters. The former is on all lists of endangered fishes; its status has been discussed recently by Hubbs and Williams (in press). The fishes in the tributary creek assemblage often present special problems. Three of them (Cyprinodon eximius, Campostoma ornatum, Notropis chihuahua) are commonly found on endangered species listings as their U.S. distribution is restricted to the creek mouths. These areas should be watched with care to reduce the possibility of extermination of this fragile assemblage. The spread of the introduced Fundulus kansae is of primary concern (Hubbs and Wauer, 1973). Future intro-

luctions of bait minnows should be avoided.

ACKNOWLEDGMENTS

We have benefitted from the encouragement by and discussion with James E. Johnson in planning our program. David S. Marsh, Linda Garrett, Danny Swepston, Floyd Potter, and Dwane Kippes participated in collecting the fishes. Ross Foster, John Vandertulip, and Pollard Rogers were hospitable hosts, provided helpful information, and permitted trespass access to or from collection sites. William Provine, Floyd Potter, and W. S. Swanson helpfully participated in the planning phases of our studies. Texas Parks and Wildlife and Departamento de Pesca de Mexico gave permission to collect fishes from the Rio Grande.

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An Overview of Riparian Forests in California: Their Ecology and Conservation[1]

Anne Sands and Greg Howe[2]

This paper is comprised of abstracts from presentations made at the Symposium on Riparian Forests in California: Their Ecology and Conservation held in Davis, California on May 14, 1977. Sponsors of the symposium were the Institute of Ecology (University of California at Davis) and the Davis Audubon Society, Inc. The purpose of this symposium was to encourage a strong alliance of individuals and agencies which will work together to establish protection for the endangered riparian ecosystems of California. Complete texts of these papers will appear in proceedings of the Davis symposium.

A SHORT REVIEW OF THE STATUS OF RIPARIAN FORESTS IN CALIFORNIA

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Riparian vegetation along streambanks, where there is usually fertile soil and an ample water supply, is a most striking feature of California's landscape. These forests appear as a green belt along permanent and intermittent water courses, sloughs, flood plains, overflow channels and oxbows, drainage ditches and lakes.

One can quickly see that the riparian community with its soil, water, and vegetation is a complex ecosystem. Cheatham and Haller (California Fish and Game, 1965), in their "Annotated List of California Habitat Types" have identified four major riparian habitats with 11 subhabitat types. Of the 29 habitat types listed in the "Inventory of Wildlife Resources, California Fish and Wildlife Plan" (Vol. III), riparian habitat provides living conditions for a greater variety of wildlife than any other habitat type found in California. It was estimated in 1963 that riparian vegetation covered about 347,000 acres -- less than one-half of one percent of the total land area of the State.

Factors affecting or adversely impacting riparian vegetation include upstream reservoir construction, levee and channelization projects, and water conservation. The reservoir, levee and channelization activities, along with clearing for agriculture, are common activities that have occurred throughout the State. Removal of vegetation is a common practice in the Colorado River area. Let's look at a riparian area from a local viewpoint. In An Island Called California, Elna Bakker (1971) states that no natural landscape in California has been so altered by man as its bottom lands. It was in the Central Valley that riparian forests were most extensive and were called gallery forests. Coupled with the extensive grasslands and rivers, large and small, a unique setting was created. It is now one of the richest agricultural areas in the world, blessed with good climate, rich soil, and until the last couple of years, ample water supplies.

The Sacramento River from Red Bluff to its mouth in the Delta is a meandering alluvial stream. The Sacramento Valley extends about 150 miles north-south and spreads about 45 miles east-west at its widest point, averaging about 30 miles wide. The area of the Sacramento Valley

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[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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so defined, is about 5,000 square miles; the area of the entire Sacramento River drainage basin is 26,150 square miles.

The Sacramento Valley is bounded by the Coast Ranges on the west, the Klamath Mountains on the north, and the southern Cascade Range and northern Sierra Nevadas on the east. The southern margin is extremely low terrain, cut by numerous branching channels of the Delta. This whole low-lying and level area is formed by the combined Delta of the Sacramento and San Joaquin Rivers. Lands of the Sacramento Valley, excluding the Sutter Buttes, are essentially flat, almost featureless, and were formed by the long-continued accumulation of sediments in a great structural trough lying between the Coast Ranges and the Cascades-Sierra Nevada. Large and small streams break up the landscape. Each had its green belt of riparian vegetation that stretched from the base of the foothills to the big river and adjacent wetlands.

Vegetation will grow on any portion of a streambed and its banks if the soil or other substrate is exposed long enough during the growing season. The fertile loam soils of the Sacramento River riparian land coupled with favorable ground water conditions and a long growing season provide near optimum conditions for the establishment of the extensive riparian forests.

The riparian woodlands occurred on the natural levees formed by the Sacramento, Lower Feather, American, and other aggrading streams. These levees rose from 5 to 20 feet above the streambed, and ranged in width from 1 to 10 miles. Based on historical accounts, it has been estimated that there were about 775,000 acres of riparian woodlands in 1848-1850. Diaries and field notes written in the early 1800's describe the extent of the forests. They also describe the lush jungles of oak, sycamore, ash, willow, walnut, alder, poplar, and wild grape which comprised almost impenetrable walls of vegetation on both sides of all the major valley rivers and their tributaries. Notes were made of giant sycamore 75 to 100 feet tall and of oaks 27 feet in circumference. By the late 1800's, however, vast tracts of riparian forests had already been cut by settlers for fuel, fences, and building materials. In addition, many thousands of acres were cleared to free the fertile alluvial soil for agricultural use. By 1952, only about 20,000 acres of riparian forests remained. Today's estimate of 12,000 acres is probably generous.

Prior to 1960, few people showed any concern for the demise of California's Riparian Forest communities. In addition, very little botanical data had been collected. During the early 60's, the first major work at removing the riparian forest remnants in an effort to protect levees occurred in the Delta. The removal of this riparian vegetation from along the lower Sacramento River was viewed with great concern by the public. Statements, both written and oral, voiced strong opposition to the methods of levee maintenance and stated that better methods should be employed so as not to destroy the esthetic beauty and wildlife habitat of the Delta waterways. Most of the same concerns exist today. However, today dedicated and enthusiastic botanists, ornithologists, mammalogists, entomologists and other field scientists are compiling species lists, recording observations, and beginning to publicize their findings. People now realize that public awareness must be coupled with political pressure.

The previously expressed concerns demonstrate a clear need for a higher order of planning and evaluation before additional irreparable alterations to this river system occur. Although no governmental body, agency, interest, or person would deliberately set out to destroy the Sacramento and other California Rivers, adjacent lands and natural resources, all too often there has been insufficient concern about the singular or cumulative effects of work accomplished by one agency or interest on the resources under the jurisdiction or responsibility of another, or how such work affects the entire riverine ecosystem and the public interest.

The realization of a Sacramento River environmental/open space corridor is a valid and long-term planning objective. Implementation is the difficult part. However, it can be done. It will require the formulation of a multigovernmental agency and concerned citizen group to see that modifications and developments are accomplished without further deterioration of the existing resources and that efforts are undertaken to enhance these same resources in the public interest while at the same time protecting the integrity of the levees and communities of the Sacramento Valley. Can one imagine a Sacramento River Parkway from the Redding area to Collinsville patterned after the American River Parkway? What a valuable recreational resource it would be to the public and especially for future generations.

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GEOLOGICAL HISTORY OF THE RIPARIAN FORESTS OF CALIFORNIA

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The plant communities that we see today are the products of evolutionary processes acting over long periods of geological time. As individual species have evolved and migrated in response to changing environments, the corresponding plant communities have changed in composition and distribution. The evidence relating to the rates and direction of this change comes from an analysis of numerous fossil deposits laid down at various times and in various regions in the past (Axelrod, 1967b). This analysis involves the systematic description of the component species in each fossil flora and the reconstruction of the ancient topographical, climatic, and vegetational settings at the site of deposition. Regional comparison of various floras then allows us to piece together the history of individual lineages and the corresponding plant communities.

The history of California's vegetation as a whole has recently been reviewed by Axelrod (1977). Three general principles emerge from his discussions. First, the modern plant communities of California are composed of taxa of diverse geographical sources. The two principal floristic elements are a "Madro-Tertiary" or southern, and an "Arcto-Tertiary" or northern element. The former includes species in such genera as Arbutus, Arctostaphylos, Ceanothus, Cercocarpus, Cupressus, Quercus (some species), and Umbellularia, while the latter includes species in such genera as Acer, Alnus, Castanopsis, Fraxinus, Picea, Quercus (some species), and Sequoia. Second, the modern communities are relatively impoverished representatives of richer, more generalized ancestral communities that include taxa related to species now found only in the southwestern United States and northern Mexico, the eastern United States, or eastern Asia. These "exotic" taxa were gradually eliminated from this region during the later Tertiary in response to a general trend to a cooler and drier climate, to a shift in the seasonal distribution of precipitation, and to progressively decreasing equability (Axelrod, 1968). Third, some of the species that are associated in these modern communities have apparently been associated, as ancestral forms in fossil communities, throughout most of California's later Tertiary and Quanternary history, covering a time span of at least 20 million years.

Distributions of the Species

One of the most important factors facilitating a species entry into the fossil record is a proximity to a site of sedimentation. As many fossil deposits accumulate along stream and lake borders, riparian taxa are generally well-represented in the record. Many of the dominant species in the modern riparian community of the Sacramento River have counterparts in the fossil record of the western United States. The present and past distributions of eight of these species are particularly informative in terms of understanding the floristic sources of the modern forest. These include Acer negundo, Alnus rhombifolia, Fraxinus latifolia, Platanus racemosa, Populus fremontii, Quercus lobata, Salix lasiandra and Salix lasiolepis.

The California sycamore, Platanus racemosa, ranges in distribution from the upper reaches of the Sacramento River southward into Baja California (Griffin & Critchfield, 1972; Little, 1976). In the Central Valley, this species is locally abundant along the Sacramento and San Joaquin Rivers, ascending their main tributaries to low elevations in the Sierran foothills. It is notably absent from the North Coast Ranges and the western side of the Sacramento Valley (Jepson, 1910). It is distributed throughout the South Coast Ranges, where it is "one of the most widely distributed aboreous species" (Jepson, 1910), and occurs in the Transverse and Peninsular Ranges of southern California (Griffin & Critchfield, 1972). The California sycamore is generally confined to sites with an abundant water supply, as along perennial streams, around springs, and in moist gulches (Sudworth, 1908). Two distinct late Tertiary species have been referred to the modern P. racemosa. To the north, Platanus dissecta is a characteristic species in the Miocene floras of the Columbia Plateau and northern Great Basin (Chaney & Axelrod, 1959). It survived into the Pliocene in this region as evidenced by the Dalles flora of Oregon (Chaney, 1944a) and the Upper Ellensburg flora of Washington (Smiley, 1963). To the south, Platanus paucidentata is a characteristic species in both the Miocene and Pliocene floras of southern California (Axelrod, 1939, 1940, 1950c, d). The distributions of these two species overlapped in central Nevada in the Miocene (Axelrod, 1956) and in central California in the Miocene and Pliocene (see Axelrod, 1944a, b; Renny, 1972). The question arises as to which of these species is more closely allied to the modern P. racemosa. Judging from the available record, it appears that P. paucidentata shows more definite relationship to the modern species (Axelrod, 1939, 1956, 1967), while P. dissecta may be more nearly related to the modern P. orientalis of the Middle East or P. occidentalis of the eastern U.S. (Axelrod,

1956; Renney, 1972). The two fossil species probably diverged from a common ancestor during the early or middle Tertiary. Leaves of the modern P. racemosa appear in abundance in the Pleistocene Soboba flora of southern California (Axelrod, 1966).

Discussion

The evidence from these fossil floras suggests that lowland riparian forests comparable to that along the modern Sacramento River have had a long and virtually continuous history in the western United States during the last 20 million years. These widespread ancestral communities showed regional variation as a consequence of major climatic differences from north to south. In southern regions, the riparian communities originally included several species with relatives in the modern forest (P. racemosa, P. fremontii, and S. lasiolepis) plus numerous taxa now restricted to the summer-wet region of the southwestern U.S. and Northern Mexico. In contrast, the original riparian communities of northern regions included several other species with relatives in the modern forest (A. negundo, A. rhombifolia, F. latifolia, O. lobata, and S. lasiandra) plus many others now confined to the summer-wet regions of the eastern U.S. and eastern Asia. It is in the intermediate areas that we first see the intermingling of these northern and southern riparian taxa that is apparent in the modern community. This is first evident in the interior (Middlegate), where the northward migration of southern taxa with spreading aridity was apparently aided by the Sierra Nevadan rainshadow. This mixed type of community subsequently appeared on the western slopes of the Sierra Nevada (Remington Hill) and disappeared from western Nevada. It became well-established over lowland west-central California by the middle Pliocene (Mulholland) and persisted in this region with some modifications down to the present. In all of these regions, we see the gradual loss of the exotic taxa in the communities as climate became progressively cooler, drier, and less equable, and as summer rainfall was reduced.

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RIPARIAN FORESTS OF THE SACRAMENTO VALLEY, CALIFORNIA

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Although edaphic and biotic influences precluded trees from most of the Sacramento Valley

in its pristine condition, the riparian lands (Mainly natural levees) supported a flourishing tree growth--valley oak, sycamore, cottonwood, willow, and other species. A number of factors contributed to their presence -- principally sub-irrigation, fertile alluvial loam soils, and relative freedom from surface waterlogging and fire. These riparian forests varied considerably in width, from a narrow strip to several miles. They also varied greatly in the spacing of the trees, from irregular open to fairly crowded stands, but were generally of sufficient extent and closeness to justify the term "forest".

Pristine Condition of the Riparian Lands

Among the first outsiders to visit the Sacramento Valley were fur trappers of the Hudson's Bay Company in the period prior to 1814. The Spaniard Luis Antonio Arguello investigated the valley in 1817 and again in 1821, and Jedediah Smith, in 1825, may have been the first American to reach the Sacramento River. However, it was not until the 1840's that significant outside influence was felt in the northern end of the Central Valley. This seclusion, however, could not survive the meteoric developments of the Americanization of California. After 1849 came a huge influx of population, lured by gold but often quickly to adopt other pursuits. These immigrants, mostly with rural backgrounds, could not overlook the agricultural promise of the Sacramento Valley. Heightening the attractions of the Sacramento Valley for agricultural settlement was its virtually vacant condition. Its relatively sparse and peaceful aboriginal population, having been greatly reduced in numbers by an epidemic in the early 1830's was unable to offer more than token resistance to the American invaders (Cook, 1955).

After recognizing the promise of the Sacramento Valley, the invading Americans quickly set about its realization. To do this called for new patterns of occupance and land use; and in the initiation of these the environment was substantially modified. The agencies of change were sufficiently drastic to transform the physical, biotic, and cultural landscape. One of the very first transformations concerned the natural levees and riparian lands, which were thickly forested in their pristine condition.

Because of the brief period between initial investigation and development, little information was accumulated on the aboriginal condition of the Sacramento Valley. One of the earliest observers to report on the riparian forests was John Work (in Mahoney, 1945) in the course of a fur-trapping expedition from his headquarters at Fort Vancouver. Writing in 1832, he described the riparian forests of the Sacramento Valley, below Red Bluff as follows:

> All the way along the river here there is a belt of woods principally oak which is surrounded by a plain with tufts of wood here and there which extend to the foot of the mountain, where the hills are again wooded.

Another early visitor to the Sacramento Valley, Captain Sir Edward Belcher, R.N., noted the profusion of oak, ash, plane, laurel, sumach (sic), hiccory (sic), walnut, roses, wild grapes, arbutus, and other small shrubs in the vicinity of the river (Belcher, 1843). He described its lower course as follows:

> Having entered the Sacramento, we soon found that it increased in width as we advanced, and at our noon station of the second day was about one-third of a mile wide. The marshy land now gave way to firm ground, preserving its level in a most remarkable manner, succeeded by banks well wooded with oak, planes, ash, willow, chestnut (sic), walnut, poplar, and brushwood. Wild grapes in great abundance overhung the lower trees, clustering to the river, at times completely overpowering the trees on which they climbed, and producing beautiful varieties of tint. . . . Our course lay between banks. . . . These were, for the most part, belted with willow, ash, oak, or plane (Platanus racemosa), which latter, of immense size, overhung the stream, without apparently a sufficient hold in the soil to support them, so much had the force of the stream denuded their roots.
>
> Within, and at the very verge of the banks, oaks of immense size were plentiful. These appeared to form a band on each side, about three hundred yards in depth, and within (on the immense park-like extent, which we generally explored when landing for positions) they were seen to be disposed in clumps, which served to relieve the eye, wandering over what might otherwise be described as one level plain or sea of grass. Several of these oaks were examined, and some of the small felled. The two most remarkable measured respectively twenty-seven feet and nineteen feet in circumference, at three feet above ground. The latter rose perpendicularly at a (computed) height of sixty feet before expanding its branches, and was truly a noble sight.

Most of the historical reports give no indication of the actual depth of the woodland. Where Belcher examined the lower Sacramento banks, probably the delta section, in 1837 he noted a belt of large oaks (including one with a trunk 27 feet in circumference at 3 feet above the ground) "about three hundred yards in depth" (Belcher 1843). John Work (Mahoney, 1945) in 1832, probably referring to French Camp Creek, a Sierra stream that flows to the delta, wrote: "the plain is overflowed and we had to encamp at the skirt of the woods about two miles from the river." Derby's report of 1849 (Farquhar, 1932) noted a two-mile-wide belt of woods on both sides of the lower Feather River. The map accompanying this report shows forest bordering all the major and minor streams in the lower Sacramento River system. Thus, riparian forest seems to have bordered the entire mapped portion of the river system from the vicinity of Clarksburg in the south to Glenn in the north. These riparian forests are shown as being fairly uniform in width, about four to five miles. Derby's map also shows riparian forests along the tributary streams almost equal in width to those of the main stream, and flanking the tributaries to the edge of the valley. On the Derby map Cache and Putah creeks have forests about three miles wide, the American and Feather rivers about four miles wide (which checks with a section of his report), and Butte Creek and Yuba and Bear rivers each have levee forests about two miles wide. A note of caution should be inserted here. Derby, although a topographical engineer, performed only a reconnaissance type of survey of the valley. This being so, together with the undoubted fact that the tree symbols are intended to be approximate rather than precise, his map should not be invested with undeserved (and unintended) accuracy. However, even with these limitations the Derby map does suggest riparian forest of substantial width and continuity, and in 1849 these were, of course, still virtually in their pristine condition.

It is highly improbable that the forest belt was of uniform width along both banks of the streams. Indeed, historical accounts clearly indicate the irregular occurrence of the trees. Belcher (1837) refers to the trees as being "disposed in clumps." Derby also speaks of "clusters of beautiful trees - oaks sycamore and ash" on the banks of the Yuba River to differentiate the forests there from those of the Sacramento and Feather rivers, which were "thickly wooded." Elsewhere he speaks of riparian forests along the Feather River "dotted" for two or three miles back from the river.

The Railroad Reports of a few years later (1855) speak of the riparian forest as being a "varying breadth, from a mile or more. . . to a meager border. Even more generally, but clearly indicating the variation of width in the riparian forests, the Railroad Reports refer to the riparian forests as "of greater or less width." Moreover, the riparian forests varied not only in width but also in tree size and density, "the number and size of trees being apparently proportioned to the size of the stream and the quantity of moisture derived from it."

The preceding discussion shows that in their pristine condition the streams of the lower Sacramento River system were flanked by forests. The historical evidence suggests that these riparian forests had varied characteristics. They included trees of all sizes, from brush to very large valley oaks or sycamores, 75 to 100 feet high, growing closely spaced or scattered irregularly in groves. On the banks of the lower Sacramento, where the natural levees are widest, the riparian forests achieved their greatest width, four to five miles. On the lesser streams and in the delta, with smaller levees, the forests formed a narrower belt, generally about two miles wide but less in the delta. Dominant species in the riparian forest were valley oak (Quercus lobata), interior live oak (Quercus wislizenii), California sycamore (Platanus racemosa), Oregon Ash (Fraxinus oregana), cottonwood (Populus fremontii), alder (Alnus rhombifolia), and several willows, (Salix gooddingii, S. exigua, S. Hindoiana, S. Lasiandra, and S. Laevigata).

Present Condition of the Riparian Forests

Although the Sacramento Valley riparian forests were an early casualty of the white man, their destruction, far-reaching as it was, was not complete. Today, parts of both banks of the Sacramento and its tributaries are bordered by many shrunken remnants of the once extensive riparian woodland. The numerous traces that remain corroborate the historical evidence examined by the author. The same tree species mentioned in the historical records - mainly valley oaks, cottonwoods, willows, sycamores, and ash - still grow on the river banks, natural levees, and channel ridges. Typically, cottonwoods and willows predominate on the immediate stream banks, whereas valley oaks are spread irregularly over the natural levees farther away from the river.

Instead of a strip measurable in miles, the forested zones along the Sacramento Valley streams are now often only yards deep, and discontinuous at that. Generally, the remaining fragments (not necessarily virgin stands, of course) form a belt less than 100 yards wide and are largely confined to bank slopes of streams and sloughs, abandoned meanders, and on the river side of artificial levees.

Examination of the Sacramento River levees reveals hundreds of larger relict stands of riparian forest. Some cover only a few acres; others several hundred. Most prominent are fully mature specimens of valley oaks in the "weeping" stage of development described by Jepson (1893) as indicating an age between 125 and 300 years. Such trees occur mostly on natural levee or channel ridge sites and are frequently around older settlements, presumably preserved for shade and ornament. Even small house lots may contain two or more oaks that predate the Anglo-American settlement period, presumably relicts of a more extensive stand. Some tracts of uncleared land near the Sacramento River (including two in Yolo County between Knights Landing and Elkhorn Ferry) are still so thickly studded with trees, including many valley oaks in the "weeping" stage, that they form the definite, if open, forest described by early visitors to the region.

Near Woodson Bridge, Tehama County, another expanse of apparently virgin riparian forest can be seen. It is still subject to almost annual overflow and is composed mainly of mature valley oaks, forming an open woodland that extends discontinuously for about a mile from the river's edge. Some splendid mature specimens of valley oak remaining from the Cache Creek riparian forest can be seen in the older residential sections of Woodland in Yolo County, which is named for the fine oak forest in which the settlement was established in 1855. Again, in and around Davis, also in Yolo County, there are many large relict oaks of the Putah Creek Forests.

In view of the general lack of trees in the Sacramento Valley, the riparian forests must have served as a source of fuel, construction, and other types of wood for a wide area. There was doubtless little incentive to conserve the riparian forests, since few of the tree species have much value as lumber. Typically the riparian forest species are fit only for low economic uses. For example, the numerous members of the genus Salix (willow) generally yield soft, light, and brittle wood of poor form for saw timber. Rather similar is the cottonwood, which is soft, brittle, not durable, and especially liable to cracking. The largest, and probably most numerous, riparian tree, the valley oak, is "very brittle, firm, often cross-grained and difficult to split or work. On account of its poor timber form the trees are rarely if ever cut for anything but fuel, for which, however, they are much used" (Sudworth, 1908).

The clearing of the riparian forest for fuel and construction also served another end: it made available for agricultural use some of the most fertile and easily managed land in the valley. In its pristine, or nearly pristine condition, much of the valley was more or less unusable for agriculture because of waterlogging and inundations. The original limitations of many valley areas have been partially overcome in recent decades with improved drainage, irrigation, and other technical advances. However, initially these limitations were such as to discourage permanent settlement and agriculture on much of the valley floor with the exception of the natural levee lands. There both settlement and cultivation were concentrated; utilization of the remainder of the valley was uncertain and irregular, with much attention paid to livestock raising. The general superiority of the levee lands still holds. The most profitable form of land use in the valley, orchards, shows a very marked concentration on levee soils, a final confirmation of their inherent suitability for tree growth.

Perhaps because the riparian forests were largely effaced during the first two or three decades of Anglo-American occupance, their existence is largely overlooked by modern students of the Sacramento Valley. But this neglected element in the landscape is by no means of negligible importance. The riparian trees served to reinforce the river banks and provide greater stability to the stream channels. They also acted as windbreaks, reducing evaporation, transpiration, and wind damage. In addition, the riparian forests provided a haven for the wildlife of the valley, furnishing cover and food sources for land and arboreal animals. Even more important was the fact that acorns, mainly from Quercus lobata, were a staple foodstuff of the Indian population. Furthermore, the forests furnished an important source of wood in an area otherwise poorly supplied.

The mere existence of the riparian forests, however, inevitably spelled their doom. The conditions, characteristic of natural levee sites, that permitted their development -- comparative freedom from flood and waterlogging, high soil fertility, and favorable soil moisture - eventually led to their destruction, for the existence of the forest was incompatible with the modes of land use initiated by the Anglo-Americans. Today, only a few traces of the formerly extensive riparian forests remain, and the Sacramento Valley exhibits a striking lack of trees.

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THE FLUVIAL SYSTEM: SELECTED OBSERVATIONS

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Human use and interest in the riverine environment extends back to earliest recorded history. We have used the river system as an avenue for transportation and communication, a water supply, a waste disposal site, and a source of power. Massive dams and channel works to dissipate the disastrous effects of floods and droughts have been constructed, and even though we can sometimes control a river we still know little about the processes which form and maintain the natural fluvial system. Only recently have we realized that rivers are natural resources that must be conserved and properly managed if we are to continue a meaningful existence.

The natural stream channel generally has sufficient discharge to emerge from its banks and flood areas adjacent to its banks on the average of once every year or two. It is this natural process of overbank flow which slowly but relentlessly builds floodplain features such as natural levees along the stream channels. The overbank flows also supply water to adjacent lowlands on the floodplain which serve as a storage site for excess runoff, much of which may enter the groundwater system. A main philosophical concession that must be recognized by more communities which compete with the riverine environment is that overbank flow (flooding) is a natural process rather than a natural hazard and that, if we are to maintain the integrity of the riverine system, we must consider the channel and floodplain as a complementary system.

Human use and interest in the fluvial environment has historically included significant drainage modification. This modification--whether termed channelization, channel works, or channel improvement--generally is controversial because of its potential adverse effects on the biological communities in the riverine environment. The loss of fish and wildlife habitat due to channel modification generally leads to simplification with less variation in the biological communities of the fluvial environment.

The reduced variability of the biological community in response to channel modification is directly attributed to the loss of variability in the physical environment. That is, stream channel modification tends to reduce the diversity of flow conditions, the diversity of bed-material distribution, and the diversity of bed forms. If environmental deterioration caused by stream channel modification is to be minimized then new design criteria must be developed such that the stream's natural tendency to converge and diverge flow and sort the bed material is maintained. That is, we must apply environmental determinism or "designing with nature" to our channel works if we are to maintain a quality fluvial environment.

The natural fluvial environment is an open system in which the channel-floodplain form and processes evolve in harmony. Significant changes in the fluvial system often occur when a geomorphic or hydraulic threshold is exceeded. These changes are partly responsible for maintaining the quasi- or dynamic equilibrium state of the stream system. Human use and interest in the fluvial environment has led to human interference with the fluvial system. This interference generally reduces the channel, floodplain and hydraulic variability and thus the biologic variability which depends on the physical environment.

The behavior of natural streams is not completely understood. Particularly important is the need to know more about relationships between erosion, deposition, and sediment concentration, as well as the effect of organic debris on stream channel morphology. In addition, if we are going to understand more about relationships between the biology of stream channels and the geomorphology, then we must begin to study complex interactions between the two. That is, we must learn more about processes which produce channel morphology necessary for biological productivity and thresholds that control the maintenance and development of the physical and biological environment.

RIPARIAN VEGETATION AND FLORA OF THE SACRAMENTO VALLEY

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Research on Sacramento Valley riparian vegetation has primarily concerned land-use patterns (McGill, 1975; Brumley, 1976) or distribution and ecology of birds and mammals in riparian habitat (Stone, 1976: Michny, Boos and Wernette, 1975; Brumley, 1976). These studies frequently include partial floristic lists or brief vegetation descriptions. Michny et al. (1975) provide quantitative vegetation data at each nine study sites. Most of these stands were apparently less than 15 m. in width and several were highly disturbed.

The objectives of this study were 1) to obtain preliminary floristic and vegetation data on several major riparian vegetation types, and 2) to use this data to a) delineate important vegetation units, b) describe structure of mature stands of riparian forest, and c) describe major seral and topographic relationships within the riparian vegetation.

The major riparian vegetation types were 1) Valley oak woodland, 2) Riparian forest dominated by cottonwood, 3) Gravel bar thickets, 4) Open floodplain communities, 5) Hydric communities.

Valley Oak Woodland

The valley oak phase of the riparian forest is typical of high terrace deposits and cut banks along the outside of meanders. These forests are dominated almost exclusively by Valley oak (Quercus lobata). Common associates include Sycamore (Platanus racemosa), willows (Salix spp.), Box elder (Acer negundo), Oregon ash (Fraxinus latifolia) and Black walnut (Juglans hindsii). Canopy height is 15-20 m. and tree cover ranges from 30-60%. A typical valley oak woodland sampled at the Cosumnes site had a density of 124.5 trees/ha and basal area of 18.35 m^2/ha. The relative density of Q. lobata in this stand is .73 and its relative basal area is .81, indicating strong dominance by Q. lobata at this site.

Valley oak woodlands are characteristically heterogeneous with areas of high density, smaller trees interspersed with more open areas of larger trees. Openings contain typical grassland species of genera such as Avena, Lolium, Hordeum and Elymus. Where tree cover is higher, the understory is characterized by poison hemlock (Conium maculatum), poison oak (Rhus diversiloba), ripgut brome (Bromus diandrus), soap plant (Chlorogalum pomeridianum), several species of Carex and Erigeron sp.

Riparian Forest

Cottonwood (Populus fremontii) dominates the riparian forest of lower terrace deposits and stabilized gravel bars along the Sacramento River. Common associates are similar to those in the valley oak woodland including willows (Salix lasiolepis, S. goddingii, S. laevigata, S. lasiandra), Fraxinus latifolia, Acer negundo, Juglans hindsii, and, on higher ground, Quercus lobata and Platanus racemosa. Canopy height is approximately 30 m. in a mature riparian forest, with a tree cover of 20-30%. Tree density in these forests is about 250 stems/ha--double that of the valley oak woodland sampled. Basal area is about 50 m^2/ha. The relative basal area of Populus fremontii is .75, reflecting its high dominance in the vegetation. The low relative density (.33-.44) of cottonwood in these stands reflects the large number of small subcanopy (10-12 m) trees (particularly Acer negundo, Fraxinus latifolia, and Salix spp). Understory species are mostly shrubs (Sambucus mexicana, Cephalanthus occidentalis, Rubus spp, Rosa Californica). Lianas such as Rhus diversiloba and Vitis californica are a dominant feature, frequently providing 30-50% ground cover and festooning trees to heights of 20-30 m. Herbaceous vetetation is < 1% cover except in openings where species such as Artemisia douglasiana, Urtica dioica, and various shade tolerant grasses may occur.

Gravel Bar Thickets

Well-stabilized gravel bar deposits are dominated by sand bar willow (Salix hindsiana) which forms dense thickets 3-5 m. tall of up to 95% cover. Common associates include saplings of Alnus rhombifolia, Acer negundo, Fraxinus latifolia, and Populus fremontii, and shrubs of mule fat (Baccharis viminea). Scattered herbaceous species are also present but cover is generally low due to the dense canopy.

Open Floodplain Communities

Sand and gravel bars which are flooded annually support a sparse vegetation cover (5-25%) dominated by small (1 m) shrubby and herbaceous perennials and annuals. The frequent disturbance normal to this habitat has favored invasion by many introduced species such as Bromus diandrus, B. tectorum, Salsola kali, Raphanus and Brassica spp, Tunica prolifera,

Polypogon monspeliensis, and Verbascum thapsus. Native species of floodplains include the small shrubs Chrysopis oregona, Trichostema lanatum, and Bidens laevis.

Hydric Communities

In old oxbows and low areas a series of hydric communities occurs. Open water supports emergent and free-floating mat vegetation containing plants such as Polygonum hydropiperoides, P. coccineum, Ludwegia peploides, Azolla filiculoides, Potamogeton crispus, Elodea spp, and Myriophyllum spicatum ssp exalbescens. Shallow water and low mud flats are dominated by Scirpus acutus (50-100% cover) 2-3 m. tall. On higher areas, where Scirpus acutus is less dominant, the species diversity of the fresh water marsh increases considerably. Hummocks in higher areas of the marsh support shrub thickets of Cornus stolonifera, Cephalanthus occidentalis, Rubus vitifolius with occasional Alnus rhombifolia and Fraxinus latifolia. It is also in this zone that the rare Hibiscus californica may be found. The Cornus and Cephalanthus hummocks are in turn invaded by understory (Alnus rhombifolia, Salix spp, Fraxinus latifolia, Rubus vitifolia, Rosa californica) species typical of the riparian forest, as well as Populus fremontii. This turns higher hummocks into Alnus dominated thickets and eventually Populus forests.

The riparian zone is a dynamic habitat: the vegetation of a given site reflects the history of flooding, aggradation, and degradation by the river. These habitats are subject to varying frequencies of flooding and of lateral erosion by the meandering river. The major riparian plant communities can be aligned along topographic gradients. The low, recent, gravel bar deposits are flooded frequently. Plant cover is low and is dominated by introduced annuals and low perennials. As gravel bars become more removed from the river and begin to stabilize, they are colonized by thickets of tall shrub and tree saplings generally dominated by Salix hindsiana. Riparian forest will become established (on lower terrace deposits) as flood frequency decreases. These junglelike gallery forests are dominated by Populus fremontii and characterized by heavy cover of lianas. Higher ground in these forests supports Quercus lobata and Platanus racemosa. The older, higher terrace deposits support stands of valley oak woodland dominated by Q. lobata. These woodlands gradually thin out and grade into valley grassland vegetation with increasing distance from the river.

Oxbows and overflow basins are characterized by a series of hydric communities. Fresh water marsh in low, wet areas is dominated by Scirpus acutus. On higher ground, this is succeeded by shrubs such as Cornus Stolonifera and Cephalanthus occidentalis. These shrub-dominated habitats appear transitional to typical Populus fremontii dominated riparian forests on higher ground.

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THE VALLEY RIPARIAN FORESTS OF CALIFORNIA: THEIR IMPORTANCE TO BIRD POPULATIONS

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Those who have heard the spring chorus of songbirds, watched herons feed their young in tree-top nests, glimpsed swarms of warblers in the early autumn greenery and tried to count wintering flocks of sparrows know first-hand the wealth and diversity of California's valley riparian forest avifauna. Today, with the last extensive remnants of these forests in jeopardy, it behooves us to weigh the importance of riparian habitat to birds and other wildlife (Gaines 1976).

Diversity

California's riparian forests support a high diversity of breeding birds (Miller 1951). Excluding Ring-necked Pheasant and Western Meadowlark (included because some census plots edge on grassland) 67 species are known to nest in the forests of the Sacramento Valley. Species richness (number of species) equals or exceeds that in any habitat for which census data is available (Gaines 1974b). Using the Shannon-Weaver species diversity index, the average species diversity for the cottonwood-

willow census plots (3.17) is considerably higher than that for the oak-cottonwood plots (2.51). Species richness, however, is only slightly higher (27 to 24). Thus the high diversity values in cottonwood-willow reflect a large number of species with relatively even densities. This high diversity seems to depend, not on edge effect or plant species diversity, but on foliage volume and foliage height profile. One of the most interesting census results is the lack of correlation of diversity with the extent that riparian forest habitat edges on openings or other types of vegetation. Most species are more or less evenly dispersed within the forest with little or no tendency to concentrate near the edge (DeSante 1972). Thus the theory that diversity is enhanced by the mixture of species from adjacent habitats may not apply to riparian forests.

Beginning with MacArthur and MacArthur (1961) a series of studies has linked bird species diversity in forest communities with foliage height diversity, foliage volume, and other habitat characteristics. This complex, fascinating subject has recently been summarized by Balda (1975). In addition to foliage, such factors as food resources, nest sites, nesting material, song posts, proximity to water, extent of habitat, geological history, and human disturbance need to be considered. Understanding these factors is important to assuring a diverse avifauna in sanctuaries, state parks, and other lands set aside as riparian forest preserves.

The percentage of breeding individuals which are migratory differs strikingly between the cottonwood-willow and oak-cottonwood census plots. In the former a large influx of birds which winter in subtropical areas, such as Western Wood Pewee, Yellow Warbler, and Northern (Bullock's) Oriole, account for 36% of the nesting bird density. In the valley oak forest, in contrast, only 4% of the nesting birds are migratory. Moister conditions in the cottonwood-willow forests may promote lusher plant growth, higher invertebrate populations and, therefore, more available food for flycatchers, warblers, and other migratory, insectivorous birds.

Based on Miller's (1951) analysis of the California avifauna, 43% of the species and 38% of the individuals breeding in cottonwood-willow habitat have a "primary affinity" to riparian forest (Table 1). In other words, in comparison to 21 other California vegetation types, these forests probably support the highest concentrations of these species. In cismontane California Red-shouldered Hawk, Yellow-billed Cuckoo, Willow Flycatcher, Bell's Vireo, Yellow Warbler, Yellow-breasted Chat, and Blue Grosbeak breed in no other forest habitat.

The breeding avifauna of California's riparian forests has intriguing affinities to that of the similarly winter-deciduous hardwood forests of eastern North America (Miller 1951). Many typically "Eastern" or "Mid-eastern" species, such as Red-shouldered Hawk, Yellow-Billed Cuckoo, Downy Woodpecker, Bell's Vireo, Warbling Vireo, Yellow Warbler, Yellow-breasted Chat, Blue Grosbeak, American Goldfinch, and Song Sparrow, have been able to colonize the arid West primarily because humid, broad-leaved riparian forests offered congenial haunts. Interestingly, all of these birds have evolved western subspecies (American Ornithologist's Union 1957). Three of these races, the Red-shouldered Hawk Buteo lineatus elegans, the Bell's Vireo Vireo belli pusillus, and the Blue Grosbeak Guiraca caerulea salicaria, breed only in the valleys of California.

Breeding Densities

The average density of nesting birds on the cottonwood-willow census plots (2088/km^2) is strikingly higher than that on the oak-cottonwood plots (1279/km^2). This difference is due primarily to migratory species. If we only consider residents, the density in cottonwood-willow (1336/km^2) is only slightly higher than that in oak (1227/km^2). Breeding bird densities in cottonwood-willow forests equal or exceed those in any California vegetation type for which census data is available(Gaines 1974). The dense, stratified cottonwood-willow forest vegetation may facilitate these high breeding bird densities. With increased trunk, branch, and foliage foraging space, bird territories may occupy less ground surface area.

The large number of migratory birds implies a seasonal abundance of insect food during the warmer months (DeSante 1972). A recent study, however, suggests that bird densities do not depend on habitat productivity (Willson 1974). In this regard it would be interesting to try to correlate bird densities in riparian forest habitats with plant productivity and invertebrate populations.

Wintering Densities

The average density of wintering birds on the valley oak plots (2439/km^2) is strikingly higher than that on the cottonwood-willow plots (997/km^2). It is interesting to compare these figures with breeding bird densities. The data suggests that oak forests support 90% more wintering than nesting birds, and cottonwood-willow forests almost the reverse. This same trend, although less pronounced, is reflected by the data on species richness and diversity.

These seasonal changes are due primarily to migrants. The large number of breeding birds which leave cottonwood-willow forests before the autumn leaf-fall deplete wintering bird densities. In the oak forests, in contrast, a large influx of migratory wintering species augments the largely resident breeding population. Most (69%) of these migrant birds subsist on seeds and/or fruits. More open conditions in the oak forests may promote the growth of herbaceous, seed-producing forbs and grasses. Berry-producing plants are probably more abundant. The available census data suggests that average bird density in oak riparian forest exceeds that in coastal mixed forests, coastal coniferous forests and chaparral (Stewart 1972). Wintering bird diversity is also high; 60 species are known to winter in the riparian forests of the Sacramento Valley.

Migration

Large numbers of passerine birds forage and shelter in riparian forest habitat during their migratory journeys. Most are foliage-gleaning or sallying insectivorous species which winter in subtropical Mexico and Central America. During the spring migration, these birds pass northwards on a broad front through the forests and woodlands of lowland California. The hills are green, the deciduous foothill oaks have just leafed out, and insect life is everywhere abundant. By late summer, however, the long dry period has seared the hills to golden brown. At this season riparian forests provide the only lush, insect-rich forest habitat in lowland, cismontane California. The importance of these forests to southward (fall) migrants cannot be underestimated.

An Endangered Habitat

Nothing better illustrates the destruction of riparian forest habitat than the decline in Californian populations of the Yellow-billed Cuckoo. This sinuous bird is closely restricted to broad expanses of cottonwood-willow forest. In the early part of this century the clearing of these forests was recognized as a threat to the cuckoo's survival (Jay 1911). At that time, they were still "fairly common" (Grinnell 1915). Only three decades later, however, Grinnell and Miller (1944) concluded that because of removal widely of essential habitat conditions, this bird is now wanting in extensive areas where once found." Recent studies have confirmed this gloomy picture. Only in the relatively large remnants of forest that hug the Sacramento River between Colusa and Red Bluff are a few pairs still known to nest within cismontane California (Gaines 1974b).

Over most of this area, once extensive riparian forest habitat has been sacrificed to civilization. The Santa Ana River in the San Bernardino Valley of Southern California is an excellent example. Here the Yellow-billed Cuckoo was first discovered nesting in California by Stephens in 1882 (Bendire 1895). During the 1920's Hanna (1937) found 24 nests in the "miles of cottonwood and willow" watered by the river. "In contrast with those good old days," he writes, "we now have very little water in Warm Creek and seldom any surface water in the Santa Ana River, the large thickets have been replaced by farms and pastures, the trees cut down, and the evergrowing population has crowded in on the old haunts of the cuckoos to such an extent that if they come here now at all they must be exceedingly rare."

In California, as throughout western North America, the last remaining groves of valley riparian forest are in jeopardy. Each year more of these forests are bulldozed and cut for pulpwood, or to make way for orchards, gravel extraction, rip-rap bank protection and urban development. Unless immediate measures are taken, this endangered habitat will no longer provide a home for the Yellow-billed Cuckoo and the many other birds and animals which dwell there.

As Eleanor Pugh (1965) recognized a decade ago, the choice is ours. "As long as housing tracts start landscaping from bare soil," she writes, "rather than plan around existing mature willows, cottonwoods, sycamores and oaks, with their entangled undergrowths so rich in the shyer birds; as long as willow shrub riparian cover is scraped away and replaced with ubly concrete channeling, breeding success will be low for many species . . . small wonder that Willow Flycatchers, Swainson's Thrushes, Yellowthroats, Yellow Warblers and Yellow-breasted Chats, though quite adaptive and once numerous, are becoming a rare sight to behold or even hear above the roar of traffic on the nearby freeway."

Table 1. The breeding riparian forest avifauna of the Sacramento Valley, California.

Species	Status	Riparian Affinity	Guild	
			Foraging	Nesting
Double-crested Cormorant (Phalacrocorax auritus)	res?	-	-	tree
Great Blue Heron (Ardea herodias)	res	-	-	tree
Green Heron (Butorides virescens)	mig	3	-	tree
Great Egret (Casmerodius albus)	res?	-	-	tree
Wood Duck (Aix sponsa)	res	2	-	tree hole*
Common Merganser (Mergus merganser)	res?	-	-	tree hole*
Turkey Vluture (Cathartes aura)	mig	8	ground carrion	tree stump
White-tailed Kite (Elanus leucurus)	res	1	ground mammal	tree
Cooper's Hawk (Accipiter cooperi)	res	1	foliage bird	tree
Red-tailed Hawk (Buteo jamaicensis)	res	5	ground mammal	tree
Red-shouldered Hawk (Buteo lineatus)	res	1	ground mammal	tree
Swainson's Hawk (Buteo swainsoni)	mig	-	-	tree
Bald Eagle (Haliaeetus leucocephalus)	res	-	-	tree
Osprey (Pandion haliaetus)	mig	-	-	tree
American Kestrel (Falco sparverius)	res	4	ground insect	tree hole*
California Quail (Lophortyx californicus)	res	-	ground seed	ground
Ring-necked Pheasant (Phasianus colchicus)	res	-	ground seed	ground
Mourning Dove (Zenaida macroura)	mig	3	ground seed	tree
Yellow-billed Cuckoo (Coccyzus americanus)	mig	1	foliage insect	tree
Screech Owl (Otus asio)	res	2	ground insect?	tree hole*
Great Horned Owl (Bubo virginianus)	res	4	ground mammal	tree
Long-eared Owl (Asio otus)	res?	1	ground mammal	tree
Anna's Hummingbird (Calypte anna)	res?	-	foliage nectar	tree
Black-chinned Hummingbird (Archilochus alexandri)	mig	1	foliage nectar	tree
Common Flicker (Colaptes auratus)	res	1	ground insect	tree hole**
Acorn Woodpecker (Melanerpes formicivorus)	res	-	foliage seed	tree hole**
Downy Woodpecker (Picoides pubescens)	res	1	bark insect	tree hole**
Nuttall's Woodpecker (Picoides nuttalli)	res	2	bark insect	tree hole**
Western Kingbird (Tyrannus verticalis)	mig	-	air insect	tree
Ash-throated Flycatcher (Myiarchus cinerascens)	mig	5	air insect	tree hole*
Black Phoebe (Sayornis nigricans)	res	2	air insect	-
Willow Flycatcher (Empidonax thraili)	mig	1	air insect	tree

[1]res = resident; mig = migratory.

[2]scale 1-8; 1 = primary affinity; 8 = species breeds in greater density in 7 other habitats (Miller 1951).

*does not excavate tree hole nesting cavity.

**does excavate tree hole nesting cavity

Table 1, continued.

Species	Status	Riparian Affinity	Guild	
			Foraging	Nesting
Western Wood Pewee (Contopus sordidulus)	mig	4	air insect	tree
Tree Swallow (Iridoprocne bicolor)	mig	1	air insect	tree hole*
Purple Martin (Progne subis)	mig	-	air insect	tree hole*
Scrub Jay (Aphelocoma coerulescens)	res	-	generalist omnivore	tree
Yellow-billed Magpie (Pica nuttalli)	res	4	generalist omnivore	tree
Plain Titmouse (Parus inornatus)	res	-	bark insect	tree hole*
Bushtit (Psaltriparus minimus)	res	4	foliage insect	tree
White-breasted Nuthatch (Sitta carolinensis)	res	-	bark insect	tree hole*
Wrentit (Chaemaea fasciata)	res	-	foliage insect	shrub
House Wren (Troglodytes aedon)	mig	2	foliage insect	tree hole*
Bewick's Wren (Thryomanes bewickii)	res	3	foliage Insect	tree hole*
Mockingbird (Mimus polyglottos)	res	-	foliage insect	tree
California Thrasher (Toxostoma redivivum)	res	-	ground insect	shrub
American Robin (Turdus migratorius)	res?	6	ground insect	tree
Swainson's Thrush (Catharus ustulata)	mig	1	ground insect	tree
Blue-gray Gnatcatcher (Polioptila caerulea)	mig	4	foliage insect	tree
European Starling (Sturnus vulgaris)	res	-	generalist omnivore	tree hole*
Hutton's Vireo (Vireo huttoni)	res?	3	foliage insect	tree

Table 1, continued.

Species	Status	Riparian Affinity	Guild	
			Foraging	Nesting
Bell's Vireo (Vireo bellii)	mig	1	foliage insect	tree
Warbling Vireo (Vireo gilvus)	mig	1	foliage insect	tree
Yellow Warbler (Dendroica petechia)	mig	1	foliage insect	tree
Common Yellowthroat (Geothlypis trichas)	mig	2	foliage insect	shrub
Yellow-breasted Chat (Icteria virens)	mig	1	foliage insect	shrub
House Sparrow (Passer domesticus)	res	-	ground seed	-
Western Meadowlark (Sturnella neglecta)	res	-	ground insect	ground
Northern Oriole (Icterus galbula)	mig	1	foliage insect	tree
Brown-headed Cowbird (Molothrus ater)	mig	1	ground seed	-
Black-headed Grosbeak (Pheucticus melanocephalus)	mig	1	foliage insect	tree
Blue Grosbeak (Guiraca caerulea)	mig	1	foliage insect	shrub
Lazuli Bunting (Passerina amoena)	mig	3	foliage insect	shrub
House Finch (Carpodacus mexicanus)	res	6	ground seed	tree
American Goldfinch (Carduelis tristis)	res?	1	foliage seed	tree
Lesser Goldfinch (Carduelis psaltria)	res?	3	ground seed	tree
Rufous-sided Towhee (Pipilo erythrophthalmus)	res	2	ground seed insect	ground
Brown Towhee (Pipilo fuscus)	res	3	ground seed insect	shrub
Lark Sparrow (Chondestes grammacus)	res?	-	ground seed insect	ground

Table 1, continued.

Species	Status	Riparian Affinity	Guild	
			Foraging	Nesting
Song Sparrow (Melospiza melodia)	res	1	ground seed insect	shrub

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HABITATS OF NATIVE FISHES IN THE SACRAMENTO RIVER BASIN

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Fish habitat in the Sacramento River Basin has been degraded severely through placer mining dredging, wetland reclamation, destruction of stream side vegetation, livestock grazing, lumbe operations, irrigation and water diversion, dams stream channelization and bank stabilization, dewatering, and domestic pollution. The general effect has been severe. Several species are now so rare as to be virtually extinct. Salmon and steelhead runs are a fraction of previously recorded levels. But the specific effect on many species is unclear because historically the study of the ecology of native species was unfashionable. Through survey and experimental studies we have been trying to reconstruct habitat requirements and preferences of native fishe in order to estimate the impact of human activities.

The task of understanding the stream fish communities has been difficult because the streams of California have been badly disturbed. The destruction of the riparian forests has been only one part of this perturbation, althoug one of the most visible. One of the first major disturbances was placer mining which destroyed salmonid spawning grounds, increased siltation, removed or covered up riparian vegetation, and drastically changed stream morphology. As agriculture became more and more important to California's economy the deterioration of aquatic habitats continued (and continues) at an ever-increasing rate. Then, as irrigation and flood control became necessary, channelization of streams started to become as common as did irrigation diversions and the construction of bypasses for flood waters. Channelization consists of vegetation removal, straightening channels (thus removing meanders), dredging the stream bed and stabilizing the banks with loose material (riprapping). This type of habitat alteration has been well documented in terms of its effect (Whitney and Baily 1959, Peters and Alfond 1964, Funk and Ruhr 1971, Barton et al. 1972, Moyle 1976a). Essentially, the environmen has been simplified: cover by stream side vegetation is removed, pools are eliminated, and undercut banks are destroyed. The substrate is made more uniform as snags and fallen logs are removed. As expected, species richness and standing crops diminish as a result. Irrigation diversions and flood bypasses often divert migra-

tory young of anadromous fishes from the main streams. The degree of impact of these diversions is not presently known; however, there is some concern that substantial mortality of young may contribute to declining chinook salmon and steelhead runs. Dewatering streams for irrigation also reduces flows, which triggers a series of changes: water temperatures increase, current is reduced, silt deposition increases, dissolved oxygen decreases, the stream becomes more shallow, and finally production decreases.

Bad forestry practices can lead to severe problems very similar to overgrazing of livestock. Small streams are often used as chutes to transport downed trees, badly damaging banks and substrate. If slash is dumped into creeks, this will cause dams to form which will impede spawning migrations, decrease flow, and increase siltation. Major problems in logging areas have also been caused by poorly designed roads which often follow stream courses. Such roads can accelerate soil erosion tremendously which dramatically increases the silt burden of the stream (Platts and Megahan 1975, Megahan and Kidd 1972, Arnold and Lundeen 1968). Fine sediment can smother embryos, alevins, and fry. Fish migrations may also be impeded when roads cross the stream and improperly designed conduits are constructed.

Numerous water diversion projects completed in California during the past 60 years have drastically altered natural hydrologic factors and increased water temperatures. A 90% reduction in flow caused average width, depth, and velocity to decrease by 22%, 44%, and 75% (Curtis 1959). A similar reduction in flow can result in a 75% decrease in riffle area, a 55% increase in shallow runs, and 96% decrease in deep, fast runs (Kraft 1972). This type of disruption of the natural hydrologic regime can explain recent imbalances in native fish populations and is more probable than interspecific competition.

The destruction of riparian forests in the Central Valley has been an important factor contributing to the changes in the fish communities, mostly because of the effect on water temperature. However, there is much we do not understand about their relationship to fish populations, particularly in regard to the use of flooded vegetation by young fish and the role of logs and other debris in increasing habitat diversity.

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ENVIRONMENTAL APPLICATIONS IN CORPS OF ENGINEERS WORK WITH REFERENCE TO RIPARIAN VEGETATION MANAGEMENT

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Two aspects of the Corps activities in which environmental applications are important are protecting the Sacramento Valley levee system with rock bank protection and projects for which plans have been developed to protect riparian trees and vegetation.

A system of about 1,000 miles of levees has been constructed to provide flood protection to about one million acres and about 800,000 persons living in the flood plain of the Sacramento River (Environmental Statement, 1972). The levee system is threatened by continuing erosion, and normal maintenance and even emergency measures

are not adequate to cope with the danger to the levees (Sacramento River Flood Control Project, 1960). In 1960 at the request of the State of California, Congress authorized the Sacramento River Bank Protection project to protect the levees (Sacramento River Flood Control Project, 1960).

Although there are some variations in the work, the usual circumstance is that erosion has progressed into or near the levee which is in danger of failure. To provide protection, a section of levee is prepared by sloping to a 1 on 2 or a 1 on 3 slope and placing the rock bank protection. All trees and vegetation in the area to be rocked must be removed to slope the bank to retain the rock. In the past, trees and vegetation were also removed from some areas adjacent to the actual worksite to facilitate equipment operation while the rock is being placed.

The following design changes were made in recent years to reduce the environmental impact of bank protection work (Environmental Statement, 1972; Bank Protection General Design, 1974):

Where feasible, contractors have been required to avoid disturbing any significant vegetation outside the limits of where the rock is placed. Besides careful equipment operation from the top of the levee, work is sometimes accomplished from a barge on the river which avoids unnecessary disturbance of vegetation to the maximum. However, barges can only navigate the deeper reaches of the river south of Colusa.

Trees have been surveyed and evaluated at the edge of the bank protection areas and all individual trees which would not interfere with construction and could be saved are marked.

At some erosion sites there is still some berm area remaining between the river and the levee. By placing rock only to the top of the berm, three things are accomplished: erosion is arrested and the levee is protected; the berm is protected, permitting vegetation growth; and there is much less rock required for construction. Protecting the berm means that trees and other vegetation on the berm will not have to be removed. Placing rock only to the top of the berm means there is much less visible rock when the river is at low flow. This appears to be the most desirable of the protection methods for environmental application. More of this type of work could be done if additional funds were available (with only limited funds work is restricted to the critical erosion sites and the other protection methods are utilized).

At some locations, the circumstances of the erosion and other factors led to a different design than adding rock for protection of the levee. Where more economical, the existing levees may be set back or relocated further from the river bank. Rock protection is placed on the riverside of the new berm, and vegetation may be planted on the berm. An example of this type of design is at a location near Monument Bend located on the right bank about one mile upstream from the Interstate 880 bridge crossing.

As each unit of bank protection is completed and turned over to the State for operation and maintenance, a supplement is provided to the standard operation and maintenance manual which covers specifically the operation and maintenance needs of that unit. Where measures are instituted for added vegetation in our construction work, it is required that this vegetation must be properly maintained.

On berm areas where there are significant trees and vegetation, the Corps has stipulated that the protected trees should remain when such sites are provided with bank protection. The State Reclamation Board has adopted a program of acquiring a stronger easement than solely for flood control purposes; this provides the landowner a higher price and requires him to leave the native riparian vegetation in place. This is an important companion feature to the berm protection design change (Bank Protection General Design, 1974).

Over the past several years, a number of experimental measures have been tested. The experimental program has had two primary purposes: to test the effectiveness of alternative bank protection methods and materials, and to determine costs of such alternative methods. The testing has been to determine engineering and economic characteristics on the effectiveness of the alternative methods as well as their environmental contribution. One important factor is whether alternative or supplemental methods are more costly to operate and maintain. Where possible, alternatives should be found that do not add significant maintenance expense.

A pilot levee maintenance study was conducted by the State of California and reported on in 1967 (Pilot Levee Maintenance Study, 1967). The study demonstrated that certain types of ground cover were compatible on levees, that some trees and shrubs may be allowed on some levees, and that in most cases unrestricted growth may be allowed on berms. The study indicated that costs of maintenance of levees would be increased with this vegetation.

The Corps has planted trees and shrubs at several selected sites along the Sacramento River (Environmental Statement, 1972) to demonstrate that such vegetation can be successfully grown, can be compatible with flood control

requirements, and can offer a significant improvement to aesthetics and other environmental aspects of the river. The most outstanding example of such a demonstration is near Monument Bend just upstream from Interstate 880 bridge. In 1967 we planted a variety of trees and shrubs along about three miles of the riverbank where the levee had been set back and the new berm protected by rock. In 1970 after three years, the vegetation has provided a significant improvement (Environmental Statement, 1972) and this is still in evidence today. The State Department of Water Resources conducted some maintenance studies on this vegetation demonstration site and in 1973 reported on the survival rates of the various species in relation to the effects of inundation by floodwaters and accidental losses by fire. Cost of manpower for levee maintenance with the planted vegetation was increased by 64 percent over costs without vegetation on similar adjacent levee areas (Sacramento River Levee Revegetation Study, 1973).

The Sacramento River and Tributaries Bank Protection and Erosion Control Investigation, authorized by the House Public Works Committee, was initiated in 1977. The purpose of this study is: to determine the Federal interest in, and responsibility for, providing bank protection and erosion control; to study alternative means and the feasibility of providing a comprehensive program to stabilize the streams, protect the levees and banks, preserve riparian vegetation, wildlife habitat and aesthetic values, and provide outdoor recreation opportunities along the river; and to select and recommend the best and most balanced plan of improvement, provided that such a plan is found feasible. Completion of the study is scheduled for 1982.

CONCLUSION

The fate of Riparian Forests in California depends upon public education and protective legislation. The first "public hearing" of the plight of these habitats was a conference in Chico, California, on May 22, 1976, which was sponsored by the Davis and Altacal Audubon Societies. A second conference was held in Davis, California, on May 14, 1977, and sponsored by the Institute of Ecology at the University of California and the Davis Audubon Society. Public awareness of the demise of Riparian Ecosystems must now be coupled with political pressure. Governmental agencies which have jurisdiction over the fate of riverbanks must be made aware of the significance and uniqueness of these ecosystems. We must study these agencies' surveys, participate in their hearings, join their advisory committees and become well armed with facts and determination. However, even federal and state agencies have restrictions on their spheres of influence. Almost 95% of the yet unspoiled remnants of riparian hardwoods in California are in private ownership. Each year more of these areas are bulldozed for orchards, cut for pulpwood and cleared for "stream bank protection."

Several approaches can be made to solve the riparian protection problem. Land use plans must be established at county and state levels to encourage recreational and open space easements as well as wildlife sanctuaries. Zoning laws should be altered to relieve land owners from heavy taxes on riparian forest (many farmers are taxed on their forests as if they were fruit orchards). Forestry management acts should be amended to protect riparian species. Private landowners should be offered reasonable alternatives to tree cutting, such as tax deductable donations of land to non-profit, private organizations like the American Land Trust, Audubon, and the Nature Conservancy. Prime riverine forest land should be purchased by conservation groups if all other measures fail. We must all publicize what we know about the Riparian Forests and work together to bring about the political changes necessary to preserve these very special and vulnerable ecosystems. Interested persons should contact the Riverlands Council, P.O. Box 886, Davis, California 95616, to receive fact sheets and legislative updates.

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Regeneration and Distribution of Sycamore and Cottonwood Trees Along Sonoita Creek, Santa Cruz County, Arizona[1]

Richard L. Glinski 2/

Abstract.--This study describes the effects of livestock grazing and streambed erosion on the regeneration and distribution of sycamore and cottonwood trees. Sycamores reproduced from root and trunk sprouts and because of this their distribution is not as likely to change significantly. Cottonwood reproduction was nearly absent in areas grazed by cattle, and was confined to the narrow erosion channel. If this regeneration pattern continues, the future maximum width of the cottonwood forest will decrease nearly 60%.

INTRODUCTION

Many Riparian Deciduous Forests in the Southwest contain extensive groves of sycamore (Platanus wrightii) and cottonwood (Populus fremontii) trees. (Plant community terminology follows Brown and Lowe 1974.) In many areas either one or both of these species are the sole tree component of the riverine habitat. They increase habitat diversity and create invaluable niches for a variety of wildlife, particularly birds (Bottorff 1974, Carothers et al. 1974, Johnson and Simpson 1971, and others).

Along Sonoita Creek in southeastern Arizona cottonwoods exclusively are used as nest trees by rare birds like the Gray Hawk (Buteo nitidus), Zone-tailed Hawk (B. albonotatus) and Black Hawk (Buteogallus anthracinus), and sycamores are the favorite nest tree of the Rose-throated Becard (Platypsaris aglaiae) (pers. obser.).

This study is an assessment of the numbers, condition, regeneration and distribution of these important trees along Sonoita Creek. It provides some basis for comparing populations of these species in areas of varied livestock grazing use. This paper also describes the effects of streambed erosion on the regeneration and future distribution of these trees in riparian habitats of the Southwest.

THE STUDY AREA

Sonoita Creek originates in the Plains Grassland about 1 km northwest of Sonoita, Santa Cruz County, Arizona, and flows in a southeasterly direction through the Desert Grassland to its confluence with the Santa Cruz River 14 km north of the Mexico-United States border. Its 51 km reach occurs along an elevational gradient ranging from 1480 to 1035 m. Its tributaries drain habitats from Boreal Forests at 2865 m elevation through Temperate Woodlands (Madrean Evergreen Woodlands) and Desert Grasslands at 1035 m elevation.

The low hills immediately bordering the creek are covered in moderate density with oaks (Quercus spp.), mesquite (Prosopis juliflora), juniper (Juniperus monosperma), cliff-rose (Cowania mexicana), mountain-mahogany (Cercocarpus sp.) and ocotillo (Fouquieria splendens). Groundcover, consisting mainly of gramma grasses (Bouteloua spp.) and love grasses (Eragrostis spp.), is moderately dense near Sonoita where soils are better developed, and sparser along the middle and lower reaches where steeper hillsides and rockier soils prevail.

The upper 19 km of the alluvial valley-floor from the headwaters to the town of

[1] Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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Patagonia consist of eroded grass- and scrub-covered plains, irrigated pastures and croplands, and remnants of a Sacaton Grass-Scrub Community. Here surface waterflow is mainly ephemeral. Streambed erosion as reported by Bryan (1925) is a common feature of this upper valley-floor. The erosion, which begins about 2.9 km southwest of Soniota, forms vertical banks 1 to 5 m high and separated by a channel from 15 to 37 m wide. The evidence of this erosion decreases progressively downstream for 5 km, first through weedy grasslands then past irrigated pastureland beginning near Adobe Canyon. For the next 5 km flood-irrigated pastures border the dry creekbed. Erosion produces cuts here less than 2 m high and occurs only locally where the creekbed borders steep hillsides.

The widest reach of this upper alluvial valley is nearly 1 km across and continues for 5.6 km downstream from the pastureland. The flood plain here supports a Sacaton Grass-Scrub Community. In early 1975 many large mesquite trees with basal diameters up to 0.6 m and a few walnut trees (Juglans major) with basal diameters of nearly 0.8 m were removed from here. This area is gradually being cleared of natural vegetation and transformed into irrigated fields. Streambed erosion is absent in the upper 4.0 km of this Sacaton Grass-Scrub plain, where the creekbed branches out among dense sacaton clumps that reach over 2 m in height, but begins about 1.6 km upstream from the lowest reach of this community. Through this eroded reach, vertical banks are 1 to 2 m high and 10 to 40 m apart. Irrigated cropland borders remnants of the Sacaton Grass-Scrub plain about 0.8 km above Patagonia.

Scattered individuals and small clumps of large cottonwood and sycamore trees occur along this upper valley-floor. The predominant tree of this upper floodplain is mesquite, which occurs mainly as a shrub or small tree up to 7 m tall.

About 0.8 km below Patagonia perennial surface water begins and continues downstream for about 19.3 km. Along this reach there is a near-continuous belt of Riparian Deciduous Forest, consisting of cottonwood, sycamore, willow (Salix gooddingii), ash (Fraxinus velutina) and walnut trees. This riparian forest varies in width from 15 to 150 m and in density of trees. It is bordered frequently by small bosques of mesquite and hackberry (Celtis reticulata).

Willow is the most abundant large riparian tree at the head of this forest, and ash is the commonest large tree along the middle and lower reaches. Cottonwood, the third most prevalent tree, is irregularly distributed throughout the forest, and densities of mature tree and sapling cottonwoods vary considerably. Sycamore and walnut are the least common large trees, and occur in small clumps or singly, mainly along the lower reaches of the forest.

The forest floor is covered with annual and perennial grasses and forbs that in some open areas form dense thickets up to 2 m tall after the onset of summer rains in July. In many places livestock grazing and human recreation eliminate summer groundcover by the following spring.

The watercourse, which normally varies in width from 2 to 5 m, is usually less than 10 cm deep, and is often lined with seep-willow (Baccharis glutinosa). In areas that are not grazed by livestock, water-cress (Rorippa nasturtium-aquaticum) blankets the flowing water most of the year.

Since much of the Riparian Deciduous Forest is within the confines of a narrow rocky canyon less than 0.5 km across, alluvial deposits are limited and extensive creekbed erosion is restricted usually to reaches near the entrances of side canyons where alluvium has accumulated. In many areas this erosion has resulted in vertically cut banks up to 4.9 m high. In 1881 a railroad track was completed along the entire length of Sonoita Creek, altering the watercourse along many reaches, including that of the Riparian Deciduous Forest. The railroad levee often constitutes the bank of the creek and contains floodwaters.

The continuity of the Riparian Deciduous Forest was disrupted in the early 1960's with the construction of Lake Patagonia. This lake covers 650 hectares beginning 11.6 km below the head of the Riparian Deciduous Forest and continuing downstream for 3.5 km. Below the dam, surface flow and patches of Riparian Deciduous Forest persist for about 2.9 km.

Thereafter, for the next 11.7 km to its confluence with the Santa Cruz River, Sonoita Creek flows intermittently with scatterings of large cottonwood, ash and willow trees.

The creek proper dissects two general soil types (Richardson in press). Ending about 10 km below Patagonia, the upper type is usually more than 1.5 m deep in old alluvium from igneous and sedimentary rocks and is composed of fine to moderately coarse textured soils with about 35 percent gravel and cobble throughout. The lower type consists of rocky, very cobbly and sandy loams less than 0.5 m deep on weathered granitic, tuff-conglomerate, or andesite-tuff bedrock. Here sediment yield is low.

The most complete climatic data for this area is from Nogales, Arizona, which lies just south of the watershed 27 km southwest of Patagonia and is 1158 m in elevation. Records from 1893 through 1962 show that maximum daily temperatures occurred during June and averaged 34.9°C; minimum daily temperatures occurred during January and averaged -1.4°C. Temperature extremes for the area were -14.4° and 43.3°C. Precipitation was biseasonal, and about 60 percent of the annual average of 396 mm fell during July through September. The driest months were May and April, respectively (Green and Sellers 1964). The spring of 1974 was an extremely dry year and some reaches of the

Riparian Deciduous Forest were without surface flow.

METHODS

From April 1974 through April 1977 I surveyed the trees of the Riparian Deciduous Forest on foot and recorded numbers, height classes, conditions, locations and evidence of regeneration of sycamores and cottonwoods. Multi-trunked trees were counted as one tree if the trunks were joined above ground level. To estimate percentage of sprouting, closely clumped sycamores were counted as an individual tree since they probably shared a common root system. I estimated the numbers of densely clustered seedlings and saplings. Tree heights were estimated and grouped into three size classes: seedling (< 2 m), sapling (2-9 m), and trees (> 9 m). I made brief notes on the conditions of mature trees, especially cottonwoods that had experienced excessive leaf-drop or canopy die-out, or ones with fully leafed canopies that had fallen over for no apparent reason. The numbers and locations of other riparian trees were only casually recorded.

At 100-m intervals I measured the width of the creekbed between the tops of the banks, and the height and approximate slope (to the nearest 30° angle) of the creek banks. To determine the maximum distance that cottonwoods occurred from the creekbed, within each 100-m interval I measured the distance between the edge of the creekbed and the cottonwood farthest removed from the creekbed on both sides of the creek. Lateral bounds of the creekbed often were easily defined by vertically cut banks, but at times were estimated for banks with shallow slopes. Frequently the railroad levee obviously confined the watercourse and was counted as a bank. Bank height and slope were not recorded where the hillside bordered the creekbed. Bank Slopes were classified as shallow ($0-30^{\circ}$), intermediate ($30-60^{\circ}$) or vertical ($60-90^{\circ}$) to the plane of the creekbed.

The Riparian Deciduous Forest was divided into five segments that differed in livestock-grazing use. The grazing practices along Sonoita Creek have varied greatly within the past 100 years, and exact grazing use, past or present, was not measured. However, it is possible to place each of the five segments in different use categories based upon livestock class or use intensity. Segment 1 is 2.7 km long, lies between 1234 and 1204 m elevation, and consists of the Patagonia-Sonoita Creek Sanctuary of the Nature Conservancy, an area fenced to exclude all livestock grazing in 1966. Segment 2 is 2.1 km long, lies between 1204 and 1189 m elevation, and has been grazed by cattle and horses for at least 50 years. Segment 3 is 0.8 km long, lies between 1189 and 1183 m elevation, encompasses the RL Ranch, and has been grazed by horses only since 1966. Segment 4 is 5.9 km long, lies between 1183 and 1143 m elevation at the head of Lake Patagonia, and has been grazed by both horses and cattle for at least 50 years. Segment 5 is 2.9 km long, lies below Lake Patagonia at elevations between 1116 and 1097 m, and has been grazed mainly by cattle for at least 50 years. The soil and vegetation in the upper third of Segment 5 was highly modified in the early 1960's when the dam was built.

RESULTS

Sycamore regeneration, distribution and condition

Sycamores reproduced mainly vegetatively by sprouts from lateral roots and trunk bases. Either root or trunk sprouts were found in 74% of mature sycamores (clumped and individual trees). I never encountered sycamore seedlings, but in Segment 4 I located one sapling that was more than 30 m from mature sycamores and was not a root sprout (Table 1).

Root sprouts occurred on 39% of the sycamores. On the average, root sprouts grew a distance of 1.0 m from the trunk bases (SD 0.5, r 3.0), were 3 m tall (SD 5, r 23), and 5 cm in diameter (SD 10, r 46). Trunk sprouts occurred on 56% of the sycamores and, on the average, sprouted 0.1 m above ground level (SD 0.1, r 0.6), were 3 m tall (SD 3, r 13) and 4 cm in diameter (SD 6, r 28). Trees with root sprouts averaged 8 sprouts per tree (SD 12, r 31), and those with trunk sprouts averaged 6 sprouts per tree (SD 10, r 30). Both root and trunk sprouts occurred on 22% of the sycamores. Root sprouts that were either less than 0.1 m tall or growing among dense debris and brush may have been overlooked, while probably all trunk sprouts were counted.

I was unable to determine what stimulates a sycamore to sprout. There was no significant correlation between either the presence of sprouts or the number of sprouts and the percent of canopy die-out, soil texture at tree base, or proximity of tree to surface water. Possibly the more latent factor of subsurface rock formations affected the presence of groundwater near individual trees and thus their tendency to sprout. The dependence of sprouting sycamores on abundant shallow water remains to be examined.

The large variance in the size of sprouts, some of which themselves were mature trees nearly 30 cm in diameter, indicates that sprouting has been a major means of regeneration along Sonoita Creek for some time. Many even-aged, large sycamores were growing in circular clumps with their trunk bases touching or nearly touching (fig. 1), suggesting that these clumped trees had been sprouts from a common parent tree that has long since decomposed.

Table 1.--Length, grazing use, and numbers of sprouts, seedling, sapling, and mature tree sycamores and cottonwoods for each of five stream segments.

	Stream Segment					Total
	1	2	3	4	5	
Sycamore						
Sprouts	0	3	0	160	99	259
(Sprouts / km)	(0)	(1)	(0)	(27)	(34)	
Seedlings (<2 m)	0	0	0	0	0	0
(Seedlings / km)	(0)	(0)	(0)	(0)	(0)	
Saplings (2-9 m)	0	1	0	0	0	1
(Saplings / km)	(0)	(0)	(0)	(0)	(0)	
Trees (>9 m)	0	7	1	35	15	58
(Trees / km)	(0)	(3)	(1)	(6)	(5)	
Cottonwood						
Sprouts	0	0	0	0	0	0
(Sprouts / km)	(0)	(0)	(0)	(0)	(0)	
Seedlings (<2 m)	400	500	700	1500	100	3200
(Seedlings / km)	(148)	(238)	(875)	(254)	(34)	
Saplings (2-9 m)	1078	11	586	20	2	1697
(Saplings / km)	(399)	(5)	(732)	(3)	(1)	
Trees (>9 m)	638	385	68	612	64	1767
(Trees / km)	(236)	(183)	(85)	(104)	(22)	
Segment length (km)	2.7	2.1	0.8	5.9	2.9	
Grazing use	none	cattle & horses	horses	cattle & horses	cattle	

Sycamores were absent in Segment 1 and most abundant in Segment 4 (Table 1) except along the reach where surface flow was absent during the spring drought in 1974. They were distributed most frequently as scattered clumps of up to 10 trees. The clumps occurred from 0 to approximately 140 m from the watercourse (m 33, SD 48). Since regeneration was mostly from sprouting, almost all seedlings and saplings occurred near mature trees.

Livestock had browsed on only 13% of root and trunk sprouts. Most sprouting sycamores were growing on steep banks or amidst brush and litter, which probably prevented cattle from browsing sprouts. Aside from the limited canopy die-out that some trees had experienced, mature sycamore trees appeared healthy. They did not respond to the severe drought in 1974 as did the cottonwoods; however, their occurrence along specific reaches of Sonoita Creek may indicate the presence of abundant surface or subsurface water, thus they would not be expected to reflect initial drought conditions that might affect other trees.

Cottonwood regeneration, distribution and condition

All cottonwood regeneration along Sonoita Creek was from seeds. In July of 1975 cottonwood seedlings about 10 cm high were ubiquitous on moist, sandy alluvium along the watercourse in all segments of the Riparian Deciduous Forest. By the following spring almost all seedlings were absent except those that had germinated in Segments 1 and 3, where cattle were excluded. In January of 1975 cottonwood seedlings were most abundant in Segment 3 (875 seedlings/km) and least abundant in



Figure 1.--Clumped mature sycamore trees.

Segment 5 (1 sapling/km). Segments 1 and 3 averaged 399 and 732 saplings/km, respectively, and Segments 2,4 and 5 averaged 5,3 and 1 saplings/km, respectively (Table 1).

All seedlings occurred below the banks, many immediately along the watercourse. Many cottonwood seeds had germinated on damp soil around isolated, ephemeral pools of rain water that had collected away from the watercourse, but the resulting seedlings wilted and died when the pools became dry several weeks after germination. A continuous supply of supplemental water (treated sewage water) existed in Segment 1, and sustained 93% of the established seedlings outside the creekbed in that segment.

Mature cottonwoods were not evenly distributed throughout the Riparian Deciduous Forest, but were densest in Segment 1 (236 trees/km) and sparsest in Segment 5 (22 trees/km) (see Table 1). The construction of Lake Patagonia Dam eliminated many mature trees from Segment 5. Within each segment cottonwoods were not homogeneously distributed, but occurred with greatest density where alluvial deposits were plentiful. Individual, small clumps or large groves of cottonwoods occurred a mean maximum distance of 26 m from either edge of the creekbed (SD 40, r 196). The mean maximum width of the cottonwood forest, including the creekbed width, was 83 m.

On numerous occasions I observed cattle grazing seedlings on sand deposits along the watercourse. I never observed horses grazing cottonwoods, although many times I saw them nose aside a cottonwood seedling to get at a nearby sprig of grass or water-cress.

The extremely dry spring of 1974 obviously affected many mature and sapling cottonwoods along the entire reach of the Riparian Deciduous Forest. Extensive leaf-drop and canopy die-out occurred in May and June, and many areas of the creekbed and forest understory at that time were blanketed with small, partially developed cottonwood leaves that ranged in color from yellow to yellowish green. Leaf-drop occurred in all segments but was most obvious in Segment 4, where the surface flow failed in May and June along a reach about 150 m long. Many trees regained fully developed canopies after the onset of summer rain in July, but others remained bare and lost large canopy limbs.

Several large cottonwood trees were uprooted in the spring of 1974, having fallen over with canopies in full leaf. The exposed roots of these fallen trees were dry and had been severed less than 1 m below ground level and less than 2 m laterally from the trunk. Uprooting occurred mainly in Segment 1, where five trees fell over. Three trees in Segment 2 and two trees in Segment 4 also were uprooted in early 1974.

Characteristics of valley-floor erosion

Along Sonoita Creek erosion has resulted in banks that are sloped in a shallow, intermediate or vertical manner to the plane of the creekbed. In many instances the shallow and intermediate slopes probably are the result of gradual trampling of once-vertical slopes by livestock. Including the railroad levee, which accounted for 12% of the sampled banks, the average slope of the banks was 56° (SD 17). Nine percent of the sampled banks were vertically cut (fig. 2). The mean height of the banks was 2.3 m (SD 1.6, r 5.8). The width of the creekbed averaged 31 m (SD 23, r 104). There was no trend in these characteristics. Each characteristic was independently and heterogeneously distributed along the valley-floor, and probably reflected the variable alluvium deposits and geometry of the valley-floor.

DISCUSSION

Effects of grazing

Regeneration and distribution of sycamore and cottonwood were affected differently by livestock grazing. The full effects of grazing on sycamore are uncertain, largely because sycamores were absent in Segment 1 where livestock were excluded so the chance of seeds germinating in this segment was reduced. In other segments livestock may have grazed some small sycamore seedlings that I had overlooked, but sycamore seedlings certainly were not common along Sonoita Creek. The germination requirements of sycamore seeds are unknown. Perhaps the soil chemistry of the eroded valley-floor has changed significantly and now inhibits either germination of seeds or growth of seedlings.

Livestock did not heavily browse sycamore sprouts for several reasons: Sprouts were necessarily associated with mature trees and

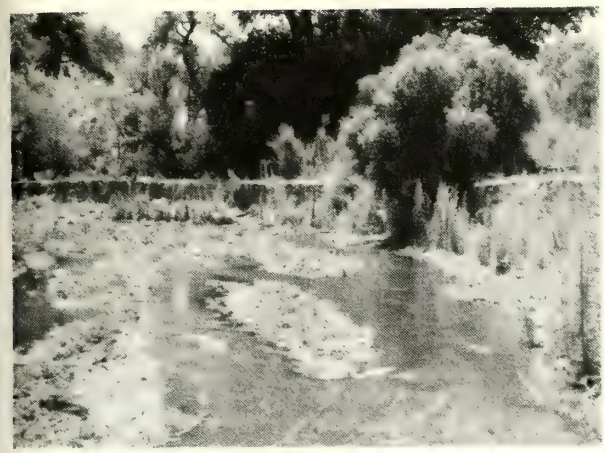


Figure 2.--Vertical-bank erosion along Sonoita Creek. Cutbank here is 1.5 m high.

thus were scattered and were neither as readily encountered by livestock, nor as easily browsed and trampled as dense clusters of seedlings on exposed alluvium. Small sprouts were frequently well protected and hidden by leaf and branch litter from the nearby mature trees and often the trunks of the parent trees obstructed browsing attempts. Several sprouting sycamores were growing on steep eroded banks or among dense brush, both of which hindered browsing. Also, the stems and leaves of sprouts may be less palatable to livestock than those of seedlings.

Because livestock may graze occasional sycamore seedlings, grazing may be preventing a limited increase in the distribution of sycamores along the streambed. Livestock did not appear to be inhibiting regeneration of sycamores by browsing on sprouts, which constituted the vast majority of sycamore regeneration along Sonoita Creek. These observations indicate that the future distribution of sycamores along Sonoita Creek will be nearly identical to the present distribution, except that where mature trees fail to reproduce vegetatively by sprouting the sycamore will disappear.

Grazing of small seedlings by cattle was the most obvious factor preventing regeneration of cottonwood. Seedlings averaging 9 cm in height and 345 seedlings/m^2 in density were commonly grazed and trampled by cattle. Both the proximity to the creek water, which was used by cattle for drinking, and the unprotected openness of the creekbed alluvium where seedlings occurred made seedlings vulnerable to trampling and grazing by cattle. Horses did not graze seedling cottonwoods, but frequently trampled young seedlings that were growing on open alluvium. Horses did strip the bark from some sapling cottonwoods that had been bent over by flooding.

Thus, by grazing seedlings cattle have severely reduced the establishment of cottonwood in the Riparian Deciduous Forest of Sonoita Creek. In Segments 2, 4 and 5, where cattle have grazed for at least 50 years, the combination of decreased establishment and normal mortality of the mature trees will eventually severely reduce in number or eliminate the cottonwoods from this forest. Dry years such as the one reported for 1974 could hasten the mortality of mature trees and the elimination of the cottonwood.

Effects of streambed erosion

Sonoita Creek flows through the Desert Grassland, a biome which has undergone major vegetational changes in the past century (Hastings and Turner 1965, and others). The erosion that is associated with these vegetation changes consists, in part, of extensive vertical cutting or channeling of the streambeds of major drainages and their tributaries by floodwaters. Both overgrazing by livestock and climatic shifts have been associated with the start of this erosion. Bryan (1925) reported that "Nearly all streams in southwestern United States flow between vertical banks of alluvium that vary in height from 10 to as much as one hundred feet. Although subject to periodic floods, these streams no longer overflow their banks, nor build up their adjacent flood-plains. Floods merely deepen and widen the channels (arroyos) which continually grow headward into the undissected valley floors of the headwater valleys and tributaries."

The extent of erosion along Sonoita Creek is limited by both the width and depth of alluvial deposits in this narrow valley-floor, although the heights of some vertically cut banks have increased up to 0.3 m from 1973 to 1976.

Two significant consequences of this channeling are the containment of floodwaters within the confines of the relatively narrow channel, and the scouring of the vegetation that occurs within the erosion channel. Precipitation that now falls within the Sonoita Creek watershed spends relatively less time in this drainage since the channel quickly transports the water along the valley-floor, preventing water dispersion laterally from the creekbed onto the adjacent floodplain. Such rapid transport may also affect the water table recharge rate.

It seems that once streambed cutting begins it is further perpetuated and accelerated by the concentrated floodwaters in the erosion channel, which transport and remove vegetation and debris that would, prior to the channel, have remained in place and promoted dispersal of less forceful floods, thus decreasing the water velocity and inducing silt deposition. The overgrazed hillsides that border Sonoita Creek no doubt assist in increasing the floodwater velocity since they support relatively

less vegetation to intercept precipitation.

I witnessed the effects of channeling on 1 July 1974 when a heavy thundershower occurred over the watershed starting about mid-afternoon. At approximately 1700 hours the water level in Segment 1 had risen almost 0.8 m, and only in unchanneled areas did it overflow laterally onto the shallow banks. The current was swift, removing or flattening vegetation on the shallow banks and scouring most aquatic plants and streamside stands of seedling cottonwoods and willows. Only seedlings that were growing among dense stands of seep-willow remained. The next morning scouring of creekbed vegetation was evident all the way to Lake Patagonia. Relatively few stream terraces had been flooded since the erosion channels or railroad levee had contained the floodwaters. In the afternoon of 2 July the water was still turbid and about 10 cm above pre-flood level in Segment 1. A layer of sand and finer silt had been deposited only on the slightly elevated banks that had been flooded and along the edges of the creekbed where the water had receded.

Coupled with recent erosion are factors of future precipitation trends. Seemingly, higher rates of precipitation would cause more intense flooding and involve a greater volume of water in the channel. Possibly the present extent of channel erosion could not contain such volumes of water and lateral flooding could result. However, if precipitation rate decreases in the future, the chance of lateral flooding would be further reduced by the channel.

The single sycamore sapling in Segment 4 that was not a root sprout had been pushed over by flooding and was partially covered by flood debris. The bark of this sapling was scraped in many places, and it appeared unhealthy and not likely to survive. Possibly sycamore seedlings are intolerant of severe flooding, and mortality from floods during the seedling stage is responsible for decreased regeneration from seeds. Root and trunk sprouts probably suffer less mortality from flooding since they are more solidly rooted and protected by parent trees.

Most cottonwood seedlings were removed by floodwaters. The cottonwood seedlings and saplings that occurred in the erosion channel usually were growing among dense stands of seep-willow, where competition for sunlight and water may affect their survival. Those occurring away from seep-willow were bent over by floodwaters and seemed unlikely to survive, and many such saplings had leaves browsed by cattle or bark stripped by horses.

While the streambed within the confines of the erosion channel transports increasingly more floodwater, the elevated terrace adjacent to the erosion channel becomes increasingly more xeric due to reduced overbank flooding outside the channel and increased depth of the water table as erosion progresses. Since cottonwood seedlings were absent from these benches, it is likely that in the absence of saturating floods they seldom contain the reliable surface water necessary for seedlings to extend tap roots to permanent water. This problem is compounded by increased distance to the ground water on benches.

The ability of mature trees to survive on the benches is questionable for they too must cope with relatively drier conditions. Most mature cottonwoods which had fallen over during the drought of 1974 were growing away from the creekbed on slightly elevated benches. Zimmermann (1969) noted that along the San Pedro River cottonwoods occurred where ground water exceeded 300 feet in depth, and he suspected that some tree species "may depend for growth during at least part of the year only on moisture in the alluvium." Where channeling has increased the depth of the water table and prevented lateral flooding onto benches, the only moisture available to vegetation on these benches may be from precipitation. For cottonwoods and sycamores this may not be sufficient to sustain growth, especially if bench alluvium and topography permit rapid runoff of precipitation. If mature sycamores require saturated alluvium for sprouting, the frequency of sprouting may decrease with increased erosion.

SUMMARY AND CONCLUSION

Sonoita Creek provided comparison of regeneration of sycamore and cottonwood trees in areas of various livestock grazing uses. It also afforded observations on the relation between regeneration and streambed erosion, which along Sonoita Creek is limited yet effective in containing and quickly transporting floodwater along the valley-floor, and ultimately in transforming the broad cottonwood forest into a relatively narrow strip of trees that grow in the erosion channel.

Livestock grazing did not appear to prevent regeneration of sycamores, which produced by sprouting from roots and trunk bases. The apparent absence of sycamore seedlings may be related to the erosion and turbid flooding that now periodically occurs in this drainage. Because of vegetative reproduction, sycamore distribution along Sonoita Creek is not likely in the near future to change appreciably from its present distribution unless mortality of sprouts occurs. An increase in soil aridity associated with the erosion channel may induce sprout and parent tree mortality.

Cottonwood, which reproduced from seed, was nearly absent in stream segments grazed by cattle, but abundant in areas grazed by horses only. Because stream flow needed for

cottonwood regeneration is confined to the eroded channel, all cottonwood regeneration is confined to this narrow habitat, which averaged 31 m wide. The present mean maximum width of the cottonwood forest including the pre-erosion remnants is 83 m. Thus the future maximum width of the cottonwood forest along Sonoita Creek will decrease nearly 60 percent if the present natural regeneration pattern continues.

ACKNOWLEDGEMENTS

Special appreciation is extended to S. J. Shellhorn and R. M. Turner for stimulating discussions of riparian ecology and for critical review of this paper. Thanks to S. B. Terrell for assisting in the field work, to W. Van Asdall and R. D. Ohmart for reviewing the paper.

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The Development and Perpetuation of the Permanent Tamarisk Type in the Phreatophyte Zone of the Southwest[1]

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Abstract.--Several species of tamarisk were introduced into the United States in the 19th century for ornamental use. Saltcedar (Tamarix chinensis Lour.) became naturalized and by the 1920's was a dominant shrub along the Southwestern rivers. Its aggressive characters suit it to be a permanent dominant in much of the phreatophyte vegetation of this region. Successful management of this vegetation for any resource must carefully consider its ecological characteristics.

INTRODUCTION

Tamarisk (Tamarix spp.), first introduced into the United States for ornamental uses in the early 1800's (Horton 1964), soon spread throughout the nation. Most dramatic, however, was its invasion onto the flood plains of the Southwestern rivers, where it soon became a major vegetation type. These stands attracted little attention until it was realized they were using large amounts of water (Horton 1973). Their aggressive spread, associated with local water shortages, resulted in many action programs to remove phreatophytes.

Robinson (1965) reported that saltcedar, as the aggressive tamarisk (Tamarix chinensis Lour.) is often called, was occupying an estimated 900,000 acres of flood-plain land by 1961. Although this acreage has now been considerably reduced by agricultural and industrial developments and various projects for control of the species for water salvage, the remaining stands are becoming increasingly important for wildlife and other resource management. In many cases, these values outweigh those of the water that might be saved by eradication of the cover. Most of these values are dicussed in accompanying papers. If should be kept in mind that flood-plain vegetation can be managed for perpetuation of wildlife habitat and still reduce water losse (Horton and Campbell 1974).

SPECIES CHARACTERISTICS

To become an aggressive part of any vegetation community, a species must establish itsel successfully under existing conditions or to spread into new habitats created by man's modifications. Of primary importance are seed production and germination, followed by successful seedling establishment.

Many phreatophyte species--such as saltceda cottonwood (Populus spp.), willow (Salix spp.) and seepwillow (Baccharis glutinosa Pers.)-- are spread primarily by abundant wind-borne seeds which germinate quickly on water or moist soil. Seeds of these species will usually lose viability rapidly, and must germinate within 2 to 4 months (Horton et al. 1960). Though the seeds will germinate rapidly, the new seedlings require wet soils for several weeks. These species thrive best in open sun, such as along sandbars or areas disturbed by floodflows. Of the species disseminated by wind-borne seed, tamarisk is the most aggressive, and when conditions are ideal, invasion will be rapid.

Seed germination of mesquite (Prosopis juliflora (Swartz) DC.) and associates is not dependent on such rigid soil-moisture conditions While germination may be started by floodflow, especially in gravel washes, seeds are spread more by animal activity, such as defecation by cattle, coyotes, etc. Thus, mesquite has spread into the grasslands and hillsides of southern Arizona where summer rains are more frequent (Schuster 1969). In the drier areas of central Arizona, however, the species is more common in alluvial soils above the deeper groundwater tables.

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[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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Root systems of phreatophyte species vary greatly. Mesquite is usually deep rooted and saltcedar can also be deep rooted. In contrast, seepwillow is shallow rooted, growing only where the groundwater is close to the surface. Arrowweed (Pluchea sericea (Nutt.) Coville) shrubs send out lateral roots just below the surface of the soils which sprout to form dense clusters over relatively large areas (Gary 1963). Some seedlings of this species have been noted, but the dense thickets are probably caused by lateral spread.

All of the aboveground portions of saltcedar will develop adventitious roots and form new shrubs if kept wet in moist soil. Gary and Horton (1965) found that 100 percent of stem cuttings would sprout at all times of the year if they are kept moist and warm. If the stem cuttings are allowed to dry, even as short a period as one day, the sprouting ability is quickly reduced. Root cuttings did not show any signs of sprouting. Wilkinson (1966), however, reported that a small percentage of completely buried root cuttings formed stem sprouts in a mist-bed in the greenhouse. How frequently similar conditions might occur in the field is not known. Spreading by lateral roots from established saltcedar shrubs has never been observed.

After burning or cutting, saltcedar shrubs redevelop rapidly; the sprouts from the root crown will grow as much as 10 to 12 feet in a year under favorable conditions. In a study of the effect of grazing upon resprouting tamarisk shrubs, cattle removed approximately 50 percent of the foliage produced. The shrubs still grew vigorously, however, and by the second year the stand became so dense that cattle would not enter the area (Gary 1960).

Cattle and probably sheep will also browse heavily on young seedlings as well as the more mature plants if the stand is open.

Mature saltcedar shrubs are more drought resistant than the native species. They are also long lived and will mature into small trees. In New Mexico, individual trees reportedly 75 to 100 years of age have not yet shown signs of deterioration due to age.

VEGETATION OF THE PHREATOPHYTE FLOOD PLAINS

The original vegetation of the flood-plain areas was determined primarily by the water supply available to the plant roots. Undoubtedly the rivers flowed rather constantly and the water tables were high in much of the valley area. The area close to the river was usually dominated by a wide band of trees, principally Fremont cottonwood (Populus fremontii Wats.), with associated willows. On the higher ground were large areas dominated by mesquite. Arrowweed was dominant in many areas. In the more saline sites, there were large patches of salt-tolerant grasses such as saltgrass (Distichlis stricta (Torr.) Rydb.), surrounded by saltbushes (Atriplex spp.) and other salt-tolerant plants.

The early pioneers used the cottonwood, mesquite, and other trees and larger shrubs for fuel and for building their homes. In the Arizona desert, the lands dominated by mesquite were some of the best soils in the valley and were soon cleared for farming. Along the Rio Grande, the first and finest farmland was created by removal of cottonwood.

These activities soon removed or at least greatly reduced the natural wooded areas along the rivers. Thus, the saltcedar found conditions ideal for rapid invasion of the flood plains. Shortly after the turn of the century saltcedar began spreading aggressively. By the 1940's, extensive areas were dominated by saltcedar along the Gila (Marks 1950, Haase 1972, Turner 1974), Salt (Turner and Skibitzke 1952, Gary 1965), and Rio Grande (Campbell and Dick-Peddie 1964) as well as along the Pecos and Colorado (Robinson 1965). It is now also found along many smaller streams, around springs and seeps, by roadsides, and in many other areas of the West wherever there is sufficient moisture to germinate the seeds and establish the seedlings.

In recent years, much of the land dominated by saltcedar has been converted to farms or industrial use near the towns and cities, or cleared for water salvage projects.

In spite of these major changes, there are still large areas occupied by wildland vegetation, although they are usually altered by man. Haase (1972), in his study of the lower Gila River, indicates that saltcedar occupies about 50 percent of the total bottom-land area. Under present conditions he feels this dominance will not be changed unless there is some marked fluctuation in the water table or in other environmental conditions. His analysis and breakdown of the communities is very similar to Marks (1950).

Somewhat similar communities were studied along the Salt River above Granite Reef dam east of Tempe (Gary 1965). The saltcedar communities were separate and distinct fromthe arrowweed, and occupied sites with shallower water tables and a silt loam soil, contrasted to the sandy loam found under the arrowweed and mature mesquite. There were a few cottonwood

trees, but not enough to be included in the analysis.

Along the Rio Grande, Campbell and Dick-Peddie (1964) found that saltcedar was the major dominant in southern New Mexico, but that cottonwood, Russian-olive (Eleagnus angustifolia L.), and other species increased upstream. These authors observed that cottonwood assumes dominance over saltcedar if the cottonwood is left to develop into a full tree without disturbance. In mature stands of cottonwood, saltcedar grows only in natural openings and along the outer edge of the cottonwood stand.

Along some flood-plain reaches, dropping water tables have reduced the stand of saltcedar, because ground water is now apparently out of reach of its roots. In the 1940's a dense stand of saltcedar extended along the Salt River from east of Mesa through Tempe and Phoenix to its confluence with the Gila River. Shrubs are now growing along this river only as widely spaced desert-type plants dependent on floodflows and rain for survival. In dry periods, these saltcedar shrubs will make almost no growth and tend to drop their leaves. They leaf out quickly when water becomes available, however.

Fires burning through such stands kill a fairly large number of plants and create an even more open stand. It is probable, in this desert climate, that shrubs must be spaced 15 or 20 feet or more apart to have sufficient root systems to withstand lengthy droughts. A heavy, dense stand will survive only where the water table is within 15 or 20 feet of the surface.

Thus, although saltcedar has aggressively spread over a large portion of the western flood plains, it has probably reached its maximum spread or is being reduced in most of the area. However, it will always threaten to invade aggressively after any change in local conditions. Its ecology must be understood if management of flood-plain vegetation is to be successful.

FUTURE OF TAMARISK STANDS

Future changes in the vegetation cover of flood plains now dominated by saltcedar is a concern of many land managers. The aggressiveness of saltcedar suggests that it will remain a dominant in most areas if conditions remain as at present and often may invade where conditions change in other types.

Seeds of cottonwood, willow, and seepwillow have characteristics similar to saltcedar. Thus, in theory they are highly competitive. However, saltcedar produces seed over a much longer period and also can become established after a summer recession flow when seeds of the other species are not present. In addition, tamarisk seedlings can tolerate drying at an earlier stage and, while often grazed, are less sought after than cottonwood and willow. Also the mature shrubs are more drought resistant which tends to eliminate many of the competing native shrubs and trees.

With the characteristics of the various species in mind, let us consider the different types of vegetation along the rivers. A dense, mature stand of tamarisk would not have any bare soil underneath, and thus there would be no opportunity for regeneration of any species. Unless subjected to fire or flood, the stand would not deteriorate. However, if cottonwood was present in the initial seedling establishmen stage, there can be a gradual increase of dominance of this species as the tree grows. This relationship can often be observed along the Rio Grande south of Albuquerque and, very rarely at lower elevations such as along the San Pedro River, south of Winkelman, Arizona. Thus, matur saltcedar stands should not be expected to yield to any invading vegetation type unless the water table drops or the existing stand is altered by man, fire, or flood.

Lowering water tables may kill a large portion of the shrubs. The degree of damage would depend upon the rapidity of the drop and the depth of the final water table. In some cases, shrubs may die back but readjust to the lower groundwater if it stabilizes at 20 feet or so. The resulting stand after the root systems are extended downwards may be nearly as dense as had previously existed.

If the water table is at 5 feet or less, saltcedar does not develop densely and the inter-shrub spaces are usually dominated by saltgrass or Bermudagrass (Cynodon dactylon (L.) Pers.) Dropping water tables in such an area will allow the saltcedar to grow dramatically and replace the grass.

Fire burning through a saltcedar stand will not kill the shrubs, as they tend to sprout vigorously unless they are growing under stress. Then as many as half of the shrubs may not survive.

Floods do, at times, remove large areas of saltcedar. If this occurs during or just before the seeds are flying, seedlings will likely be established along the edges of the receeding flows more aggressively than other species. Sometimes, such as after flash summer floods, drying is too rapid for seedling survival. Buried root crowns or above-ground portions of branches and smaller stems will often sprout, however, even if conditions are not favorable for seedling establishment.

STUDIES IN *TAMARIX* TAXONOMY

The identification of saltcedar and its proper relationship to Old World form has long been confused. The taxonomy of *Tamarix* is difficult primarily because of the lack of distinct identifying floral characteristics, and the great variation among plants in the same community. Major confusion is caused by the length of the blooming season (March to October in desert climates) with changing inflorescence types and floral characters as the season progresses. Thus, accurate species identification requires several collections from a shrub to sample seasonal variations.

The early floras usually listed *T. gallica* as the introduced species. This terminology continued until McClintock (1951), in a study of horticultural tamarisks, stated that *T. gallica* was a rare shrub in the West, and the common aggressive saltcedar was *Tamarix pentandra* Pall.

Baum (1966), after extensive study of the genus *Tamarix* at the Hebrew Univeristy, Jerusalem abandoned the name *T. pentandra* because it did not follow the standard rules of nomenclature. He considered the widespread American tamarisk, after examining material from various American herbaria, as consisting of two species: *Tamarix ramosissima* Lebed. and *Tamarix chinensis* Lour. (Baum 1967). *T. gallica* was reported as occurring mostly on the Texas Gulf Coast. *Tamarix africana* Poiret and several others were reported as horticultural species.

After detailed studies of many shrubs of diverse species and forms obtained from various American and Old World localities and grown on the Arizona State Univeristy Farm as well as herbarium specimens collected elsewhere in the United States, I feel that our aggressive saltcedar, though extremely variable, should be considered as one species and not two as outlined by Baum. The oldest synonym applied to the aggressive tamarisk group is *Tamarix chinensis* Lour.; thus this name should now be accepted for the species so commonly naturalized in the West.

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Avian Use of Saltcedar Communities in the Lower Colorado River Valley[1]

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Abstract.--Bird densities and bird species diversities (BSD) in saltcedar (Tamarix chinensis) stands of the lower Colorado River Valley were determined on a seasonal basis from May 1974 through February 1977. Comparisons were made between six saltcedar structural types as well as on a community level with seven other vegetation types. A method of determining the relative value of the communities, as well as the saltcedar structural types, based on density, density with 10 percent doves, BSD, BSD with 10 percent doves, number of species, structural diversity, and size of census area is described. Results showed the saltcedar community supported fewer birds than native communities, although tall, dense stands were valuable for nesting doves and rarer bird species in riparian communities along the lower Colorado River.

INTRODUCTION

Events of the past century have resulted in tremendous changes in the flora and fauna of the lower Colorado River Valley. The Colorado River has been channelized and controlled, and vast stretches of honey mesquite (Prosopus juliflora) have been converted to agricultural use--a practice which has continued at an accelerated rate in the past few years. These conditions have favored the Brown-headed Cowbird (Molothrus ater) and have reduced or extirpated the breeding populations of such species as the Yellow Warbler (Dendroica petechia) and Bell Vireo (Vireo bellii).

This loss of habitat has also been accompanied by a deterioration of the remaining bottomland by the now well-entrenched exotic saltcedar (Tamarix chinenses). First recorded in Arizona in the late 1800's, saltcedar was not an important species until after 1910 (Robinson 1965). Nevertheless, it is now present in pure communities or mixed with virtually all riparian community types, being absent only from a few stands of honey mesquite. Knowledge concerning those avian species which utilize saltcedar is essential for those agencies involved with river or riparian vegetation management.

Areas containing saltcedar are regularly swept by fire, as demonstrated by the fact that 21 of the 25 stands involved in our study have burned during the last 15 years. The other four stands of saltcedar developed after some other form of severe disturbance. Many of these areas obviously supported another community type in the past. Saltcedar is a fire-adapted species and shows a greater recovery rate than the native riparian species. Willow (Salix gooddingii) and arrowweed (Tesseria sericea) respond quickly after fire while honey mesquite shows slower growth. Species such as cottonwood (Populus fremontii) are killed during fire. With the initiation of a burn cycle, the dominance of an area by saltcedar becomes successively more complete (see Horton, these proceedings).

1/ Paper presented at the symposium on Importance, Preservation and Management of Riparian Habitat, Tucson, Arizona 9 July 1977.

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METHODS

Structural Types

The saltcedar community (stands in which saltcedar is virtually the only tree was divided into six structural types, based on distribution and density of foliage at varying heights, as explained elsewhere in these proceedings (Anderson, Engel-Wilson, Wells, and Ohmart). Structural types IV and V (trees not dense and seldom taller than 5 or 3 m, respectively) represent typical stands found in the lower Colorado River Valley. Data were gathered in these areas from the summer of 1974 through February 1977. Beginning in 1976 data were gathered from about 18 transects averaging over 0.8 km in length, using censusing techniques described by Anderson, Engel-Wilson, Wells, and Ohmart (these proceedings). These included one transect in structural type I (dense vegetation at 10 to 20 m), established in March 1976; one transect in type II (dense vegetation at 5 to 10 m), established in June 1975; two transects in type III (trees dense, seldom exceeding 6 m), established in March 1976; four transects in type IV, eight transects in type V and two in type VI (sparse vegetation representing regrowth after disturbance), established in 1974.

Ranking Technique

We developed the ranking technique for assessing the relative value of structural types of saltcedar stands and of saltcedar compared to other community types. A rank value for bird density in the structural types of saltcedar was determined using all doves and 10 percent doves, by assigning the smallest value (1) to the structural type with the greatest density and the largest value (n) to the one with the smallest density. This was repeated using numbers of species and BSD with all doves and with 10 percent doves. A mean rank for these parameters was calculated for five seasonal periods throughout the year. The average of these seasonal values was the rank assigned to a particular type.

The relative value of saltcedar compared with other community types was achieved by assigning the smallest score to the community type with the greatest average density (or number of species, or BSD's, all structural types combined) and the largest score to that community type with the smallest density (or number of species, or BSD's) as described above for saltcedar structural types.

The number of species may increase with the diversity or size of area censused. We attempted to compensate for this by ranking the most heterogeneous community or structural types with the greatest diversity or largest census area last.

We assumed that each of the parameters considered were of equal importance, a point of potential contention.

RESULTS

Densities and Diversities

Types IV and V, 1974-76

Data for three consecutive summers (May, June, July) from structural types IV and V were fairly consistent. Large dove densities in type IV in 1976 and in type V in 1975 (Table 1) resulted in relatively depressed BSD's in those years. Type IV diversities with 10 percent doves were higher than those of type V in 1974 and 1975. Dove densities for 1976 in type IV increased threefold from 1975, depressing the diversity value just lower than that of type V.

Fall (October, November) data for type V were similar in the first two years but showed a rather dramatic increase in all parameters in 1976 (Table 1). Type IV showed greater values in 1975 than in 1974 and increased further in 1976. Few doves were present at this time of year and this is reflected in slight differences in BSD's with 10 percent doves and BSD. We feel that increased densities in the fall of 1975 and 1976 over 1974 can be traced in part to the much milder conditions which existed during the late fall and winter seasons, allowing increased and prolonged use of the saltcedar community, particularly by small wintering insectivores.

Diversity values appeared to be more closely correlated with the structural parameters than were densities or species numbers. For example, in the fall of 1974 and 1976, densities in type V were greater than those of type IV; the reverse was true in 1975. Diversity values, however, were always greater in type IV.

Types I - VI, 1976

Bird densities in the six saltcedar structural types generally follow the same annual pattern of low winter numbers, increasing in the spring and peaking in the summer (Table 2). Densities dropped in late summer and continued dropping through the following winter. Spring (March-April) densities were apparently

Table 1.--Summer and fall densities, diversities, and number of species in saltcedar. Structural types IV and V, lower Colorado River Valley 1974-1976.

Structural Type	Year	Density	Density with 10% Doves	BSD	BSD with 10% Doves	Number Species
SUMMER						
IV	1974	120	64	2.2801	2.7009	19
IV	1975	126	77	2.4377	2.6237	19
IV	1976	241	98	1.9255	2.6055	18
V	1974	129	91	2.4135	2.5871	21
V	1975	182	120	2.4022	2.5631	22
V	1976	131	86	2.4411	2.6760	20
FALL						
IV	1974	42	40	2.3878	2.3062	14
IV	1975	76	75	2.4033	2.3644	16
IV	1976	105	103	2.6336	2.5934	22
V	1974	60	55	2.2369	2.1274	14
V	1975	75	63	2.0881	2.0126	14
V	1976	110	110	2.5772	2.5772	22

related to structure. Abert's Towhee (Pipilo aberti) provides a good example of a species whose density was strongly correlated with structure in saltcedar, with 1, 5, 14, 19 and 27 birds per 40 ha in types V through I respectively.

The preference of nesting doves for dense vegetation at 3 to 6 m is strongly reflected in the bird density value of type II saltcedar in the summer. There were, in fact, as many doves in this type as birds of all species in most of the other structural types.

Type II continued to show a large dove population in late summer (August-September), although types I and III had higher populations of birds of other species. Type V had the greatest diversity values and a relatively large number of species, but by far the lowest density.

The dove population was extremely low in the fall. Diversities and numbers of species, however, continued to show an inverse relationship with structure as in late summer.

Densities during the winter (December-January-February) season of 1976-77 were high compared with the fall, and especially high compared with the previous winter (Table 2). The majority of these birds, however, were small insectivores such as the Ruby-crowned Kinglet (Regulus calendula), Orange-crowned Warbler (Vermivora celata), and Yellow-rumped Warbler (Dendroica coronata). As previously mentioned, the relatively mild winter was at least partly responsible for the densities of these birds. The monthly totals for these species in the saltcedar community as a whole decreased throughout the winter, whereas the total found in the cottonwood-willow community was higher in January and February than it was in December. This demonstrates that cottonwood-willow maintained a high value for these species throughout the winter--unlike saltcedar (Table 3).

COMPARISON OF COMMUNITIES

Knowledge of the value of the different saltcedar structural types is necessary, but more important is the relative value of the saltcedar community as compared with other community types--many of which are either being displaced by saltcedar or lost in other ways. Communities to be compared include six riparian communities as well as desert wash and citrus orchard communities.

Community Densities

Bird densities in saltcedar were consistantly greater than those in arrowweed only (Tables 4 and 5) while numbers of species in seasons other than winter were comparable with other communities (Table 6). Winter densities

Table 2.--Densities, diversities and number of species in six saltcedar structural types, lower Colorado River Valley, December 1975 - February 1977.

Structural Type	December January February	March April	May June July	August September	October November	December January February
Total Density (N/40 ha)						
I	--	146	290	213	165	107
II	42	111	503	363	268	275
III	--	101	316	296	129	119
IV	25	39	241	187	105	50
V	29	54	131	89	110	125
VI	293	89	226	280	171	153
Density 10% Doves (N/40 ha)						
I	--	136	193	183	165	107
II	37	91	238	177	267	272
III	--	81	156	239	129	115
IV	20	28	98	155	103	49
V	27	50	86	75	110	125
VI	132	83	157	104	95	103
BSD						
I	--	2.1739	2.5036	1.8976	1.9097	1.7062
II	2.0383	2.2129	2.0411	1.8211	2.2582	1.9667
III	--	1.7179	1.8521	2.3969	2.3934	2.2683
IV	2.4850	2.5366	1.9266	2.4985	2.6336	2.3853
V	2.5825	2.4147	2.4411	2.7965	2.5772	2.0141
VI	1.6514	2.2435	2.5269	1.5361	1.8744	2.0174
BSD 10% Doves						
I	--	2.0930	2.7312	1.7129	1.9097	1.7062
II	1.9487	2.0597	2.5425	2.1160	2.2397	1.9367
III	--	1.6070	2.1643	2.3143	2.3934	2.2128
IV	2.5191	2.6939	2.6055	2.3894	2.5934	2.3272
V	2.5284	2.3437	2.6760	2.7972	2.5772	1.9908
VI	2.5715	2.1687	2.6214	2.7467	2.5127	2.2271
Number Species (N/40 ha)						
I	--	12	25	8	12	11
II	8	13	20	13	18	19
III	--	6	19	26	20	18
IV	12	15	18	23	22	14
V	15	13	20	24	22	19
VI	21	17	24	25	21	23

of birds in saltcedar are greater than those found in saltcedar-honey mesquite and arrowweed but included the greatest percentage and nearly the greatest dove densities of all communities. Densities decreased from summer through the winter while densities with 10 percent doves remained fairly stable through the fall. Although doves comprised fully 50 percent of the summer density in the saltcedar community, there were actually more doves in all of the other community types, excepting arrowweed and desert washes. There was a distinct relationship between departure of doves and rising BSD values from August through November (Tables 7 and 8). Bird densities in honey mesquite rose sharply in October-November, and bird densities in desert wash and saltcedar-honey mesquite not only increased from late summer to fall, but the greatest number of species occurred at this time.

Table 3.--Winter densities of small insectivores in cottonwood-willow and saltcedar communities, lower Colorado River Valley, 1976.

Community	Month	Ruby-crowned Kinglet	Yellow-rumped Warbler	Orange-crowned Warbler	Total	Percent of Total Population
Cottonwood-Willow	Dec	323	258	83	664	51
	Jan	340	516	92	984	57
	Feb	321	327	109	757	45
Saltcedar	Dec	152	535	47	734	59
	Jan	176	130	32	338	46
	Feb	89	100	6	195	32

Table 4.--Total densities for eight community types December 1975 - November 1976, lower Colorado River Valley.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	148	172	336	262	210
Screwbean Mesquite	73	109	318	307	183
Honey Mesquite	193	193	323	195	270
Saltcedar-Honey Mesquite	42	111	295	184	177
Saltcedar	54	71	216	177	129
Desert Wash	68	115	176	118	185
Arrowweed	18	23	124	141	99
Orchard	158	158	678	540	135

Table 5.--Densities including 10% doves for eight community types December 1975 - November 1976, lower Colorado River Valley.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	134	151	223	195	201
Screwbean Mesquite	58	82	174	218	159
Honey Mesquite	161	166	169	148	265
Saltcedar-Honey Mesquite	40	91	170	151	176
Saltcedar	26	62	119	126	120
Desert Wash	67	106	121	98	185
Arrowweed	17	23	101	135	99
Orchard	144	97	132	178	128

Table 6.--Number of species for eight community types found in the lower Colorado River Valley from December 1975 through November 1976.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	28	40	35	41	34
Screwbean Mesquite	16	27	24	33	26
Honey Mesquite	19	30	22	28	27
Saltcedar-Honey Mesquite	16	20	20	19	22
Saltcedar	10	19	25	27	26
Desert Wash	16	20	20	21	30
Arrowweed	8	13	21	23	18
Orchard	17	20	18	25	17

Table 7.--BSD for eight community types found in the lower Colorado River Valley from December 1975 through November 1976.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	2.7401	3.1762	2.8494	3.1817	2.9502
Screwbean Mesquite	2.6422	2.9067	2.4015	2.4451	2.8087
Honey Mesquite	2.1850	2.8608	2.1850	2.6826	2.6206
Saltcedar-Honey Mesquite	2.5428	2.4575	2.327	2.5476	2.5095
Saltcedar	1.8071	2.8537	2.405	2.7038	2.8167
Desert Wash	2.5047	2.2293	2.364	2.5706	2.7706
Arrowweed	1.9652	2.4643	2.665	2.7037	2.5160
Orchard	1.8823	2.0460	0.693	1.3052	2.2837

Table 8.--BSD with 10% doves for eight community types found in the lower Colorado River Valley from December 1975 through November 1976.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	2.6941	3.2125	3.2225	3.3940	2.9067
Screwbean Mesquite	2.7721	3.1914	2.9040	2.4758	2.8263
Honey Mesquite	2.1561	2.8937	2.8276	2.7997	2.5844
Saltcedar-Honey Mesquite	2.4869	2.4888	2.675	2.4660	2.4971
Saltcedar	2.6848	2.8443	2.883	2.8544	2.7827
Desert Wash	2.4718	2.1516	2.564	2.5943	2.7706
Arrowweed	1.9652	2.4229	2.6108	2.6562	2.5160
Orchard	1.7105	2.2931	1.897	2.3454	2.1917

USE BY VARIOUS GUILDS

The percentage of the total lower Colorado River Valley population of sixteen of the more common breeding species (representing six guilds) which would occur in saltcedar, using 40 ha of each of the six riparian community types, should approximate 16.6 percent (1/6 the population of a species) if there were no selection for a particular vegetative type by any of these species, i.e. if they were evenly distributed in all community types. Two of three small (<15 gm) insectivorous species apparently exhibited no selection against saltcedar (Table 9), occurring in densities at or slightly above the expected. Woodpeckers demonstrated much less flexibility in adapting to saltcedar, possibly as a result of body size in relation to tree limbs and trunks suitable for making nest cavities. The Ladder-backed Woodpecker (Picoides scalaris), the smallest species, was more common than the Gila Woodpecker (Melanerpes uropygialis); the Common Flicker (Colaptes auratus), the largest species, did not occur in saltcedar at all. Fifty to 86 percent of the population of three medium-sized insectivores were found in structural types I and II, but only the Summer Tanager (Piranga rubra) used saltcedar to any significant extent (Table 9). The density of Abert's Towhee was slightly above that which would be expected by chance while other ground feeders (Gambel's Quail, Lophortyx gambelii and the Crissal Thrasher, Toxostoma dorsale) were slightly below expected values (Table 9). All four species of granivores occurred at greater than expected levels although a constantly wet condition was probably the greater attractant for the Song Sparrow (Melospiza melodia), considered here to be a granivore.

OVERALL VALUE OF SALT CEDAR TO BIRDS

Value of Structure

The structural types found in saltcedar (all types except type VI) were ranked to

Table 9.--Differential use of community and structural types by foraging guilds of birds in the lower Colorado River Valley, 1976.

Species	Total/240 ha all communities	Total in saltcedar 40 ha	% total in saltcedar	% population in each structure, all communities					
				I	II	III	IV	V	VI
Small Insectivores									
Verdin	108.60	10.17	9.4	5.0	15.8	20.4	25.1	15.2	18.5
Lucy's Warbler	87.37	17.50	20.1	23.4	29.0	15.2	15.6	11.1	5.7
Black-tailed Gnatcatcher	34.03	5.83	17.1	27.2	9.6	9.6	23.7	20.8	9.0
Woodpeckers									
Ladder-backed Woodpecker	31.80	2.17	6.8	26.9	29.9	15.1	12.1	6.2	9.9
Gila Woodpecker	11.57	.17	1.4	42.0	31.3	11.1	5.9	3.7	5.9
Medium-sized Insectivores									
Northern Oriole	46.30	5.67	12.2	18.1	31.6	22.0	14.5	6.5	7.2
Summer Tanager	8.83	3.00	34.0	73.1	13.7	11.4	1.8	0.0	0.0
Yellow-breasted Chat	11.00	.17	1.5	33.2	37.4	17.9	10.2	1.3	0.0
Cactus Wren	7.73	.67	8.6	11.5	23.0	20.1	16.1	8.6	20.7
Ground Feeders									
Abert's Towhee	102.55	20.50	20.0	12.3	25.0	29.8	13.4	9.8	9.4
Crissal Thrasher	21.10	2.83	13.3	0.0	21.7	25.0	21.0	21.3	11.0
Gambel's Quail	93.25	13.67	14.7	0.6	23.5	12.0	18.1	24.7	21.1
Granivores									
Song Sparrow	9.17	2.00	21.8	69.7	4.8	21.6	3.8	0.0	0.0
Blue Grosbeak	40.78	9.50	23.3	15.3	22.6	19.7	14.0	12.1	16.3
House Finch	5.92	3.17	53.5	56.5	15.7	9.4	5.7	7.1	5.6
Brown-headed Cowbird	105.63	18.50	17.5	18.3	27.4	20.8	14.7	11.6	7.2
Flycatchers									
Ash-throated Flycatcher	65.52	6.83	10.4	10.8	24.7	17.4	17.9	12.0	17.2
Western Kingbird	8.37	1.00	12.0	4.8	45.2	12.1	17.4	4.8	15.5

determine their relative value. Type II can be seen to be, overall, the preferred structure by birds in general, followed by types I, III, V, and IV, the values of the last two being very close (Table 10). The changes in the avian community that occurred when saltcedar reached a structure of type II or I were significant not only in terms of increasing densities of some birds but also in the addition of species. For example, the White-winged Dove (Zenaida asiatica) and the Mourning Dove (Zenaida macroura), Abert's Towhee, Lucy's Warbler (Vermivora luciae) and the Black-chinned Hummingbird (Archilochus alexandri) were much more abundant in type II than in type III. Type I attracted the Song Sparrow and relatively high densities of Abert's Towhee as well as the Summer Tanager and Yellow-breasted Chat (Icteria virens) in the summer.

Relative Community Value

The communities, including the two non-riparian communities, were analyzed to determine their overall relative value to birds during 1976 using the "ranking" technique discussed above. Ranked in this way cottonwood-willow communities proved the most valuable, followed by honey mesquite, screwbean mesquite, saltcedar-honey mesquite, desert wash, saltcedar, orchard and arrowweed (Table 10). Since orchards do not represent a naturally occurring community, it can be seen that saltcedar is only slightly more valuable than arrowweed (Table 11).

DISCUSSION

It has been demonstrated that the saltcedar community does not compare favorably with essentially native communities (except arrowweed, which lacks trees). Nevertheless, in the face of present environmental conditions and continuing loss of native vegetation, a concomitant increase in the proportion of the riparian habitat dominated by saltcedar is inevitable. Of particular interest was the comparison between saltcedar and orchards. The occurrence of these communities in the lower Colorado Valley has been relatively recent, and both present a uniform monoculture regardless of structural types. The birds have thus responded in a similar overall manner to these exotic communities.

Although it would appear that few species of birds are actually attracted to saltcedar during the breeding season, the addition of one or more of the native tree species, even in small numbers, would no doubt greatly enhance the overall attractiveness of an area. Addition of cottonwood or willow trees would add nest site potential, an important community component, especially for the woodpecker and flycatcher guilds. Screwbean or honey mesquite, if infested with mistletoe, would attract frugivores, a guild entirely missing from pure saltcedar.

Managing areas of saltcedar for structural types I and II appears to have significant potential (Ohmart and Anderson, MS[5]/). Saltcedar type II and mature orchards support the greatest densities of doves (Mourning Dove in orchards, both species in saltcedar type II), which are important game species in the lower Colorado River Valley. Saltcedar type I provides a habitat for avian species which are normally restricted to cottonwood-willow communities, such as the Summer Tanager, and is another important reason land managers should strongly consider managing saltcedar communities. Fire prevents saltcedar from reaching maturity and/or persisting as mature communities for any length of time along the lower Colorado River. Maintenance of mature

Table 10.--Relative value of saltcedar structural types to birds as determined by Ranking Technique, lower Colorado River Valley, March 1976-February 1977. Lower rank indices indicate greater relative value.

Structural Type	Density	Density 10% Doves	BSD	BSD 10% Doves	Number Species	Size of Census Area	Grand Rank
I	2.6	2.2	3.8	3.8	4.0	1.0	2.90
II	1.2	1.6	3.6	3.6	2.6	1.2	2.30
III	2.6	2.6	3.6	3.4	3.2	2.8	3.03
IV	4.6	4.6	1.8	1.4	2.8	4.0	3.20
V	4.2	4.0	1.0	1.8	1.8	5.0	3.13

5/ Manuscript in preparation discussing management alternatives of saltcedar communities for wildlife.

Table 11.--Relative value of eight community types in 1976 using Ranking Technique. Lower rank indices indicate greater relative value.

Total Density		Density with 10% Doves		Number of Species	
Honey Mesquite	2.0	Cottonwood-Willow	2.0	Cottonwood-Willow	1.0
Cottonwood-Willow	2.4	Honey Mesquite	2.4	Honey Mesquite	2.8
Orchard	2.6	Screwbean Mesquite	3.8	Screwbean Mesquite	3.2
Screwbean Mesquite	4.0	Orchard	4.0	Desert Wash	4.4
Saltcedar-Honey Mesquite	5.4	Saltcedar-Honey Mesquite	4.4	Saltcedar	4.8
Desert Wash	5.4	Desert Wash	4.8	Saltcedar-Honey Mesquite	5.4
Saltcedar	6.4	Saltcedar	6.8	Orchard	5.4
Arrowweed	7.8	Arrowweed	7.8	Arrowweed	6.8

Bird Species Diversity (BSD)		BSD with 10% Doves		Community Diversity		Grand Rank	
Cottonwood-Willow	1.0	Cottonwood-Willow	1.2	Saltcedar-Honey Mesquite	1.0	Cottonwood-Willow	2.47
Screwbean Mesquite	3.2	Screwbean Mesquite	2.6	Arrowweed	1.0	Honey Mesquite	3.50
Saltcedar	3.4	Saltcedar	2.7	Desert Wash	3.0	Screwbean Mesquite	3.83
Arrowweed	4.2	Honey Mesquite	4.0	Orchard	4.0	Saltcedar-Honey Mesquite	4.40
Honey Mesquite	4.8	Arrowweed	5.2	Honey Mesquite	5.0	Desert Wash	4.63
Desert Wash	4.8	Desert Wash	5.4	Screwbean Mesquite	6.2	Saltcedar	5.10
Saltcedar-Honey Mesquite	4.8	Saltcedar-Honey Mesquite	5.4	Saltcedar	6.6	Orchard	5.27
Orchard	7.8	Orchard	7.8	Cottonwood Willow	7.2	Arrowweed	5.47

saltcedar communities for 20 or more years would enhance the overall value of this plant species for birds.

ACKNOWLEDGEMENTS

We wish to thank the many field biologists who have helped in collecting data. We are grateful to Jack Gildar for computerizing the data. The efforts of the secretarial staff in typing early drafts and of Penny Dunlop and Katherine Hildebrandt in typing the final manuscript are greatly appreciated. We thank Jane Durham, Jake Rice, James Bays, and Jeannie Anderson for critically reading early drafts of the manuscript. The research was funded through grant number 14-06-300-2415 from the U. S. Bureau of Reclamation.

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Influences of Riparian Vegetation on Aquatic Ecosystems with Particular Reference to Salmonid Fishes and Their Food Supply[1,2]

William R. Meehan, Frederick J. Swanson, and James R. Sedell[3]

Abstract.--The riparian zone has important influences on the total stream ecosystem including the habitat of salmonids. Shade and organic detritus from the riparian zone control the food base of the stream and large woody debris influences channel morphology. Temporal and spatial changes in the riparian zone, the indirect influences of riparian vegetation on salmonids, and the effects of man's activities are discussed.

INTRODUCTION

Streamside vegetation strongly influences the quality of habitat for anadromous and resident coldwater fishes. Riparian vegetation provides shade, preventing adverse water temperature fluctuations. The roots of trees, shrubs, and herbaceous vegetation stabilize streambanks providing cover in the form of overhanging banks. Streamside vegetation acts as a "filter" to prevent sediment and debris from man's activities from entering the stream. Riparian vegetation also directly controls the food chain of the stream ecosystem by shading the stream and providing organic detritus and insects for the stream organisms.

[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

[2]The work reported in this paper was supported in part by National Science Foundation Grant No. 7602656 to the Coniferous Forest Biome and Grant No. BMS75-07333 to the River Continuum Project. This is contribution No. 283 from the Coniferous Forest Biome and No. 5 from the River Continuum Project.

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WHAT IS RIPARIAN VEGETATION?

Riparian vegetation is at the interface between aquatic and terrestrial environments. It has, therefore, been defined and examined from a number of perspectives. Plant ecologists speak in terms of riparian species and plant communities. The riparian zone may also be defined geographically in terms of topography, soils, and hydrology. We prefer to take a functional approach; that is, to consider riparian vegetation as any extra-aquatic vegetation that directly influences the stream environment.

Consequently, in defining riparian vegetation we must consider the full scope of its biological and physical influences on the stream. Riparian vegetation regulates the energy base of the aquatic ecosystem by shading and supplying plant and animal detritus to the stream. Shading affects both stream temperature and light available to drive primary production; therefore, the balance between autotrophy and heterotrophy is determined by multiple functions of riparian vegetation.

Although imperfect, the stream order system(Leopold et al. 1964) is a useful way to classify elements of a drainage system. In small and intermediate-sized streams (up to about fourth-order) in the Pacific Northwest, riparian vegetation exercises important controls over physical conditions in the stream environment. Rooting by herbaceous and woody vegetation tends to stabilize streambanks, retards erosion, and, in places, creates over-

hanging banks which serve as cover for fish. Above ground woody riparian vegetation is an obstruction to highwater streamflow, sediment and detritus movement, and is a source of large organic debris. Large organic debris in streams (1) controls the routing of sediment and water through the system, (2) defines habitat opportunities by shaping pools, riffles, and depositional sites and by offering cover, and (3) serves as a substrate for biological activity by microbial and invertebrate organisms (Triska and Sedell 1976; Swanson et al. 1976; Sedell and Triska 1977; Anderson et al. in press).

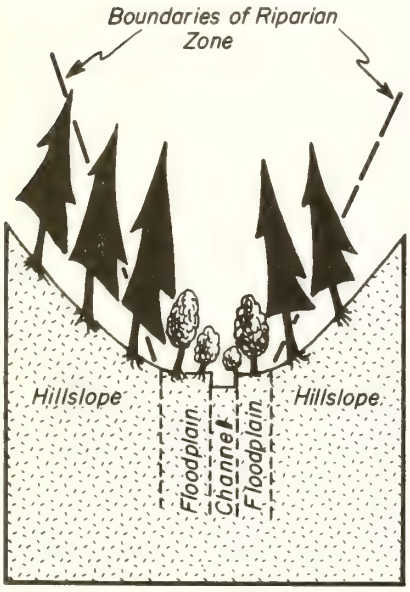
The influences of riparian vegetation on coniferous forest stream ecosystems in the Pacific Northwest are summarized in figure 1. In a functional approach to defining riparian vegetation, all floodplain vegetation as well as trees on hillslope areas which shade the stream or directly contribute coarse or fine detritus to it are considered part of the riparian zone. In the Pacific Northwest, vegetation in the zone of riparian influence includes herbaceous ground cover, understory shrubby vegetation (commonly deciduous), and overstory trees on the flood plain (generally deciduous) and on hillslopes (generally coniferous).

VARIATIONS OF THE RIPARIAN ZONE IN TIME AND SPACE

The character and importance of riparian vegetation varies in time and space. Temporal variation involves patterns of vegetative succession following disturbances. Major processes of vegetation disturbance include wildfire and clearcutting (important to upslope vegetation) and damage due to impact of sediment and floating ice or organic debris during flood flows. Spatial variation occurs along the continuum of increasing stream size from small headwater streams to large rivers.

Temporal Variations of Riparian Zones

The effectiveness of a riparian zone in regulating input of light, dissolved nutrients, and litterfall to the stream varies through time following wildfire, clearcutting, or other disturbances (fig. 2). In the first decade or two following deforestation, streamside vegetation may increase in height growth and biomass more rapidly than upslope communities. Shading of the stream by riparian vegetation gradually diminishes the potential for aquatic primary production until maximum canopy closure. Deciduous shrubs and trees within the riparian zone will contribute most



RIPARIAN VEGETATION

SITE	COMPONENT	FUNCTION
above ground-above channel	canopy & stems	1. Shade-controls temperature & in stream primary production 2. Source of large and fine plant detritus 3. Source of terrestrial insects
in channel	large debris derived from riparian veg.	1. Control routing of water and sediment 2. Shape habitat-pools, riffles, cover 3. Substrate for biological activity
streambanks	roots	1. Increase bank stability 2. Create overhanging banks-cover
floodplain	stems & low lying canopy	1. Retard movement of sediment, water and floated organic debris in flood flows

Figure 1.--Extent of riparian zone and functions of riparian vegetation as they relate to aquatic ecosystems.

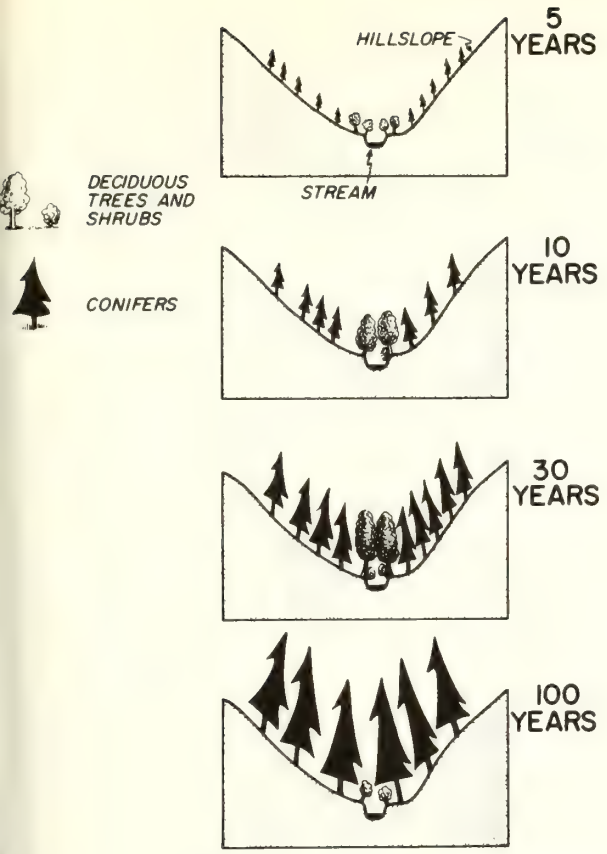


Figure 2.--Changes in the riparian zone through time.

of the litter inputs during early watershed recovery. These deciduous inputs will more readily decompose than coniferous litter which dominates inputs late in watershed recovery and in old-growth forests (Sedell et al. 1975; Triska and Sedell 1976).

The temporal development of riparian zones causes a shift in the energy base of the stream from algae to deciduous leaves to a combination of deciduous and coniferous leaves. The last stage in riparian succession is a complex mosaic of coniferous overstory, deciduous shrub layer, and herbaceous ground cover. Streams flowing through older, stratified forests receive the greatest variation in quality of food for detritus-processing organisms. Herbaceous vegetation is high in nutrient content, low in fiber, and utilizable by stream organisms as soon as it enters the stream. Leaves from the deciduous shrub layer are higher in fiber content and take 60 to 90 days after entering the stream to be utilized fully by stream microbes and insects. The conifer leaves take 180-200 days to be processed. Thus there is a sequencing of utilization of inputs from these three distinctive riparian strata. The results for the stream are rich and diverse populations of aquatic insects which are keyed into the timing and varied quality of the detrital food base.

Spatial Variation of Riparian Zones

A stream should be viewed as a continuum from headwaters to mouth (Vannote, personal communication; Cummins 1975, 1977). The influence and role of riparian vegetation will vary with stream order and position along the continuum. Some broad characteristics of streams and rivers are depicted diagrammatically in figure 3.

Extensive networks of small first to third order streams comprise about 85 percent of the total length of running waters (Leopold et al. 1964). These headwater streams are maximally influenced by riparian vegetation (the ratio of shoreline to stream bottom is highest), both through shading and as the source of organic matter inputs. Even in grasslands, the distribution of trees and shrubs follows perennial and, occasionally, intermittent watercourses except where land use practices have resulted in removal or suppression of riparian vegetation.

These low light, high gradient, constant temperature headwater streams receive significant amounts of coarse particulate matter (CPOM > 1-mm diameter). Their most striking biological features are the paucity of green plant life or primary producers (algae and vascular plants) and the abundance of invertebrates that feed on CPOM (Cummins 1974, 1975). Shredders reduce detritus particle size by feeding on CPOM and producing feces which enter the fine particulate organic matter (FPOM < 1-mm diameter) pool.

Although the transition is gradual and varies with geographical region, the shift from heterotrophy to autotrophy usually occurs in the range of third- to fourth-order streams (fig. 3). Rivers in the range of fourth- to sixth-order are generally wide and the canopy of riparian vegetation does not close over them. Direct inputs of CPOM from the riparian zone are lower in larger rivers because of the reduced ratio of length of bank to area of river bottom.

The importance of floodplain vegetation (mainly deciduous) increases relative to the hillslope species (mainly coniferous) and in a downstream direction. Generally this is so because the floodplain width increases downstream and the canopy opening over larger streams allows greater arboreal expression of deciduous riparian vegetation. Development of deciduous riparian trees is suppressed by shade along small streams.

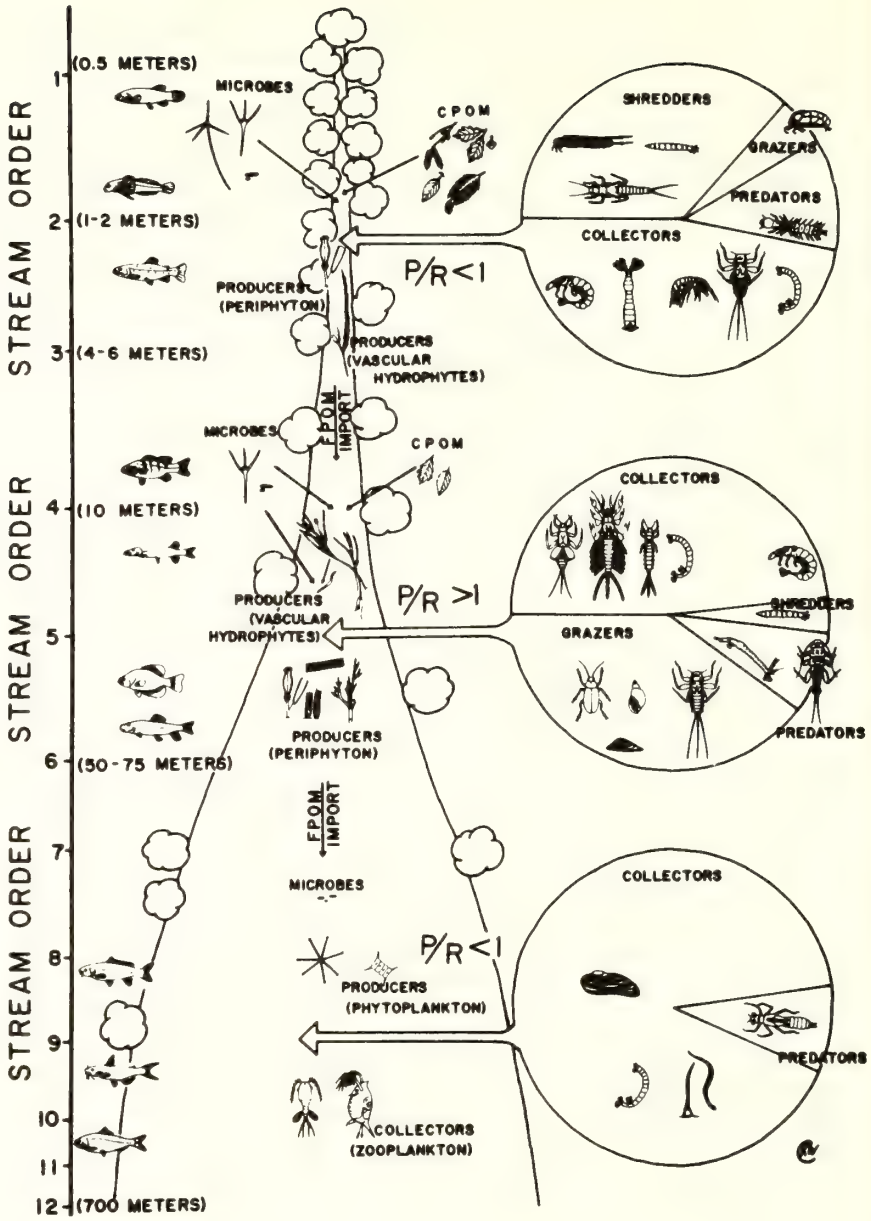


Figure 3.--A diagrammatic representation of some of the changes that occur in running water systems from headwaters to mouth. The organisms pictured are possible representatives of the various functional groups occurring in the size ranges of streams and rivers. Although a large network of smaller tributaries coalesce into larger rivers, the system is shown diagrammatically as a single headwater through all orders to the river mouth (orders and approximate ranges of stream or river width are shown at the left margin). The decreasing direct influence of the adjacent terrestrial vegetation of the watershed and increasing importance of inputs from upstream tributary systems is a basic feature of the conceptual scheme. The proportional diagrams at the right show the changes in relative dominance of invertebrate functional groups from headwaters to mouth. Important shredders include certain species of stoneflies, caddisflies, and craneflies that feed on CPOM (coarse particulate organic matter). Dominant collectors are netspinning caddisflies, blackflies, clams, and certain midge species which filter FPOM (fine particulate organic matter) from the passing water. Also, certain species of mayflies, midges, oligochaetes, and amphipods (may also function as shredders) gather particles from the sediments. Grazers or scrapers include certain species of caddisflies, mayflies, snails, and beetles. In addition to the fish shown at the left, the major predators are helgramites, dragonflies, tanypod midges, and certain species of stoneflies. The midregion of the river system is seen as the major zone of plant growth (algae, or periphyton, and rooted vascular plants) where the ratio of gross primary production (P) to community respiration (R) is greater than 1. Fish populations grade from invertebrate eaters in the headwaters to fish and benthic invertebrate eaters in the midreaches to benthic invertebrate and plankton feeders in the large rivers. (Modified from Cummins 1975).

FOOD BASE AND BIOLOGY OF FORESTED STREAMS

The food base for the biological communities of forest streams consists of leaves, needles, cones, twigs, wood, and bark. The large boles which help shape the small stream are usually biologically processed in place. The input of bole material to the stream is not a regular annual occurrence. Leaves, cones, twigs, lichens, and other components of fine litter have a reasonably predictable timing of input to and export from streams. Of the organic material which falls or slides into first-order streams every year, only 18-35 percent may be flushed downstream to higher order streams. These streams are very retentive, not mere conduits exporting materials quickly to the sea. Sixty to 70 percent of the annual organic inputs are retained long enough to be biologically utilized by stream organisms. Big wood debris dams serve as effective retention devices for fine organic material, allowing time for microbial colonization and insect consumption of this material. Functionally the invertebrates of streams flowing through forests have evolved to gouge, shred, and scrape wood and leaves and to gather the fine organic matter derived from breakdown of coarser material (Cummins 1974; Anderson et al.in press).

Woody debris and leaves, the two major allochthonous components entering a stream from the riparian zone, operate in different ways in relation to quantity, quality, and turnover time of standing crop. The leaves form a small pool of readily available organic material, while the wood forms a large pool of less available organic matter. The slowly processed wood also constitutes a long term reserve of essential nutrients and energy. The composition, metabolic structure, and nutrient turnover time of the particulate organic pool effectively provide both flexibility and stability within the system.

The amount of debris processed in a defined reach of stream depends on two factors: (1) the nature of the debris (abundance and species of wood or leaves) and (2) the capacity of the stream to retain finely divided debris for the period of time required to complete processing. Debris undergoing utilization by stream biota may either be utilized fully within a stream reach or be exported to a downstream reach. Processing continues as small debris moves along the drainage because export from one reach constitutes downstream input. Processing includes both material used metabolically by bacteria and fungi and those debris pieces physically abraded by mineral sediment or by insect consumption. In all cases, the debris is broken into smaller pieces which increases the surface- to-volume ratio and makes a debris particle increasingly susceptible to microbial attack.

Wood in streams is a substrate for biological activity and it creates other habitat opportunities by regulating the movement of water and sediment. To measure the importance of large organic debris from the riparian zone in streams, Swanson and Lienkaemper (unpublished data) examined several streams and measured percent of stream area in (1) wood, (2)wood-created habitat, principally depositional pools, and (3) nonwood habitat such as bedrock and boulder cascades. In a 245-m section of Mack Creek, a third-order stream flowing through an old-growth Douglas-fir stand in the western Cascade Range, Oregon, 11 percent of the stream area is in wood, 16 percent in wood-created habitat, and 73 percent in nonwood habitat. Figure 4 shows an example of the distribution and quantity of debris in a section of Mack Creek. In a first-order tributary draining 10 ha, wood comprises 25 percent of the stream area and another 21 percent is habitat created by wood. Much of the biological activity by detritus-processing and consumer organisms is concentrated in the areas of wood and wood-created habitat. Each habitat type has a different faunal composition.

Wood Habitat Community

Wood habitat communities are distinctive. The primary utilizers are beetles, midges, and snails. In addition to the food supplied to the major wood eaters, the surface area and large number of protective niches on wood afford considerable living space and concealment. Wood is used for oviposition, as a nursery area for early instars, for resting, molting, pupation, and emergence. Because of its unique capillary properties, it affords an ideal air-water interface where gradients of temperature and moisture can be selected by different taxa for various activities.

Wood-Created Habitat

The depositional areas behind large debris are prime areas for processing leaf material and the fine organic matter derived from wood. These areas are richer than the wood habitat community both in numbers and biomass of invertebrates. Leaves and the shredders (primarily caddis- and craneflies) are concentrated in these areas. Many of the shredders feeding here will use the wood habitat to molt, pupate, and emerge.

The difference in invertebrate biomass on leaves and wood is attributed primarily to differences in food quality. Although both are low in nitrogen compared with periphyton, seeds, or fresh macrophytes, the wood is so high in the refractory components lignin and cellulose that it becomes available at a very slow rate. The greater surface area and penetrability of leaves results in microbial con-

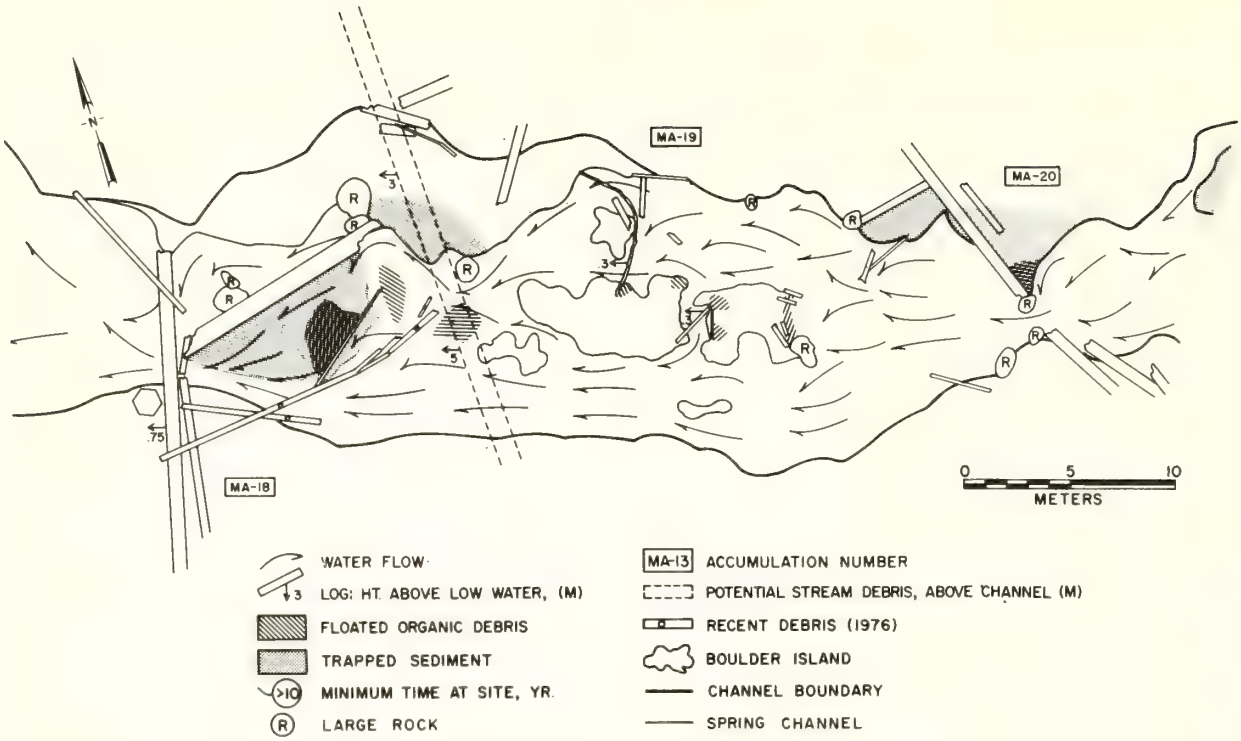


Figure 4.--Distribution of debris in a section of Mack Creek, western Oregon. Courtesy of George W. Lienkaemper.

ditioning occurring within months, compared with years for wood. Conditioning is a key factor in the debris becoming available as food for the invertebrates.

RELATIONSHIP OF RIPARIAN VEGETATION TO SALMONIDS

Direct Influences

The previous discussion has described how riparian vegetation contributes to primary stream productivity through input of organic material and nutrients which are utilized by various components of the stream biota. These relationships directly affect the production of fish by establishing the basic components of the food chain which eventually lead to the fish themselves. Likewise, necessary portions of salmonid habitat are created by large pieces of debris from the riparian zone. Logs and debris jams create pools and protective cover. This type of habitat also provides communities of benthic organisms different from those associated with the shallower and faster waters of riffles and runs. This increase in diversity of invertebrates provides a more useable food base for the fishes, which depend to a great extent upon them. A large part of the diet of fish in the family Salmonidae (the various Pacific salmon, trout, and char) is aquatic insects and other invertebrate organisms.

Indirect Influences

In addition to the effect of riparian zone material which directly becomes a part of the stream system, streamside vegetation has many important indirect influences on the habitat of salmonids.

Water Temperature

The principal source of heat which raises water temperatures is direct solar radiation (Brown 1969). Consequently, streamside vegetation is important in maintaining water temperatures suitable for spawning, egg and fry incubation, and rearing of anadromous and resident salmonids. Several studies in the last decade have demonstrated how streamside vegetation directly controls water temperature (Levno and Rothacher 1967, Brown and Krygier 1970, Meehan 1970, Burns 1972). The literature is also rich with documentation of the effects of streamside canopy removal on stream temperatures (Hall and Lantz 1969, Meehan et al. 1969, Brown and Krygier 1970, Burns 1972, Moring 1975).

Stream temperature is directly proportional to surface area and solar energy input, and inversely proportional to streamflow (Gibbons and Salo 1973). Therefore, small forested streams are the most susceptible to temperature

change. The insulating effect of riparian vegetation is thus of primary importance in maintaining acceptable stream temperatures in the many small streams which cumulatively produce a significant portion of the salmon and trout populations of the Western United States.

Sediment

Another major function of riparian vegetation is to act as a buffer or "filter" against sediment and debris which would otherwise be deposited in the stream. Surface runoff is a primary vehicle for the transportation of sediment to streams from adjacent sources, either natural or man-created. The herbaceous communities within the riparian zone are effective in reducing the impacts of this runoff, and the larger shrubs and trees prevent larger debris from entering the stream channel. The value of streamside vegetation for stream protection has been quantified in economic terms by Everest (1975).

Sediment which affects salmonids occurs in two general forms. As suspended sediment, it can be harmful if concentrations are high and persistent (Cordone and Kelley 1961). Under these conditions, silt may accumulate on the gill filaments and actually inhibit the ability of the gills to aerate the blood, eventually causing death by anoxemia and carbon dioxide retention.

Bedload sediment, however,probably limits salmonid production more than suspended sediment. Excessive deposited sediment reduces the flow of intragravel water, which in turn limits the supply of oxygen available to incubating eggs and alevins, and hinders the removal of metabolic waste products (Sheridan 1962, Vaux 1962, Cooper 1965, McNeil 1966). Bedload sediment may also act as a physical barrier, preventing the emergence of newly hatched fry up through the gravel (Koski 1966, Fall and Lantz 1969).

Another effect of sediment is the alteration of habitat used by aquatic insects (Wagner 1959) which directly relates to the growth and condition of the fish which utilize them. Although biomass may not decrease, the species composition may change such that the new forms are not as readily available to the fish.

Cover

The extensive rooting of herbaceous riparian vegetation aids in streambank stabilization. As a result, where streamside vegetation is intact, the occurrence of undercut banks is higher. This is prime habitat for trout and young salmon. Overhanging streamside vegetation also acts as escape cover and in some instances as a deterrent against predation by birds and mammals.

Insects

As discussed earlier, riparian vegetation contributes to the food base of stream biological communities in the form of wood and other organic debris. In addition, streamside vegetation is important in directly providing insects to the stream which then become part of the available fish food. Terrestrial insects which are associated with the various strata of the riparian zone become "accidental" fish food items. Many of the aquatic insects use streamside vegetation during emergence and in the adult stages of their life cycle.

EFFECTS OF LAND USE PRACTICES

Many of man's activities affect the riparian zone to varying degrees. We must consider logging and road construction to be among the most severe disturbances. Until recently it was common practice to clearcut timber to the stream's edge. In addition to removing the trees which provided shade to the stream surface, the understory vegetation and ground cover were usually cut down or severely disturbed. In recent years, the importance of the smaller streams has been more fully recognized and buffer strips along streams are often left.

The riparian zone is also affected by livestock grazing. In addition to cropping off much of the herbaceous vegetation along streambanks, livestock also use the smaller shrubs and young trees as forage. As a result, much of the ground cover and many of the plants which provide shade to small streams are removed. The soil along the streams is compacted by trampling, and together with the removal of the "filtering" plants a situation is created which promotes the addition of fine sediment to the streams. Wild ungulates also utilize the riparian zone, but their presence is much less noticeable than that of cattle and sheep. A workshop was conducted in Reno in May 1977 to bring together existing knowledge on the relationships between livestock and fisheries, wildlife, and range resources. A large part of the material which was discussed at this workshop concerned the riparian zone, and will soon be available.[4]

[4] USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California (in press).

SUMMARY

The riparian zone is a very important area influencing the habitat of salmonids. Much of the wood which forms the food base for stream biota comes from the riparian zone. This same wood, when it falls or slides into a stream, has an important role in shaping the stream and creating its habitat types. Streamside vegetation provides shade to the stream surface, thereby maintaining water temperatures acceptable to salmonid fishes. The roots of woody and herbaceous plants provide streambank stability and help to create overhanging banks, an important component of salmonid habitat. Streamside vegetation provides habitat for the later life history stages of aquatic insects and for terrestrial insects which accidentally become part of the food utilized by salmonids.

When the riparian zone is affected by man's activities, the quality of fish habitat will likewise be affected.

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Ecological Study of Southwestern Riparian Habitats: Techniques and Data Applicability[1]

Bertin W. Anderson, Ronald W. Engel-Wilson,

Douglas Wells and Robert D. Ohmart [2]/

Abstract.--Techniques used in a comparative ecological study of bird and rodent populations along the lower Colorado River are presented. Data were gathered to examine not only faunal community relationships to various plant community types but also to gain detailed knowledge of an individual species' vegetational preference and its niche within the riparian habitat. Examination of parameters such as habitat breadth, habitat and niche overlap and dispersal is instructive in the determination of a species' niche and is of use for the resource manager and the theoretical ecologist alike.

INTRODUCTION

Agencies responsible for the management of natural resources are beginning more to recognize and approach management from the ecosystem level as opposed to monospecific research. As a result of this, many governmental agencies are currently developing ecosystem approaches to management or are providing financial support for studies of this nature. A central problem in implementing management based on the ecosystem approach is often a direct lack of knowledge concerning species' requirements and the relationships and composition of faunistic communities.

This paper reports on the field techniques employed and the applicability of data gathered during a comparative ecological study of the avian and small mammal populations in riparian habitat along the lower Colorado River. The approach is primarily synecological in that the focus is on entire floral and faunal populations and their relationships within the riparian ecosystem; the design of the study also allows collection of in-depth autecological data.

The specific objectives of the study were as follows: 1) to determine the relative value of each of the various plant communities to birds and small mammals found within the riparian system; 2) to examine ecological relationships of the avifaunal and mammalian components within each plant community type; 3) to determine how these relationships, and other factors, are important in population regulation and habitat selection. In addition to gathering in-depth and repeatable data which would satisfy the above requirements, field techniques had to be chosen and developed which would be suitable for studying a large area with a limited number of personnel.

The study area embraced all of the riparian vegetation in the lower Colorado River Valley between the Mexican boundary north to Davis Dam--a distance of approximately 425 km. The width of the valley varies from 0.8 km to 16 km. Much of the natural vegetation has been cleared and developed for agriculture or other purposes. The remaining riparian vegetation is scattered throughout the valley in tracts of various sizes.

[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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VEGETATION MEASUREMENTS

Establishment of study sites in relatively homogeneous stands of riparian vegetation was begun in June 1973. As personnel increased (currently 13 persons), more study sites were added, and by April 1976, 84 sites had been established. Study sites varied in length from 0.8 to 1.6 km. Initially a line was cleared 0.7 m wide and 0.8 to 1.6 km long. The sampled area was considered to extend laterally 126 m from the center line on each side. Each line was numbered and designated as orienting in a specific compass direction. As a vegetation type map was developed for the entire valley, every attempt was made to sample each plant community type by line establishment, proportionate to their total area in the valley. The level of quantification of the plant community types was such that if a sample area of a given structure was lost (i.e. cleared or burned), another could be established without drastically affecting comparisons between years.

Although great care was taken to locate sample sites in relatively homogeneous communities, vegetation analyses indicated that considerable variation existed along many of the sites. To quantify this variation along each study site and to better understand bird-habitat relationships, each lateral portion of the study site from the center line was subdivided into 150 m long intervals. Each 150 m interval was marked with surveyor's tape and a wooden stake on which was painted the distance from the start of the line. A line 1,500 m long, orienting north to south, now was conceptualized as being composed of twenty distinct 150 m units--ten on the west side and ten on the east side of the line. Hereafter, each distinct (150 m) unit will be referred to as a plot.

Tree Counts

A direct tree count was conducted along all transects. The count area extended 15 m laterally to the line on each side. Within each 30 m advancement along the transect, all trees were counted and listed as to tree species, size class of trees (<3 m or >3 m) and presence of mistletoe (Phoradendron sp.). Tree counts could either be summed to yield number of trees per plot or number of trees along the line in the study site.

Relative Foliage Volume

The relative foliage volume within each study site and within each plot was determined using the board technique (MacArthur and MacArthur 1961). The number of sampling points per study site was dependent on the number of plots comprising each study site. The vegetation within each plot was sampled in three predetermined locations. The sampling points were at 15, 76, and 137 m along the line from the beginning point. Each foliage volume sampling point was displaced laterally 4.6 m from the line. At each sampling point a measuring tape was used to determine the distance to the nearest foliage that would cover approximately 50 percent of the foliage board. This was determined at 0.15, 0.6, 1.5, 3.0, 4.6, 6.0 m and every 3.0 m height interval thereafter until the tallest foliage present was measured. The plant species to which the distance measurement was taken at each height interval was also recorded. Measured distances were converted to m^2 of foliage per m^3 of space using the formula

$$K = \frac{\log_e 2}{D},$$

where K is foliage density and D the measured distance. The foliage density within each plot for the various height intervals and for total foliage density was determined by using the average of the measurements from the three sample points within each plot. The foliage density for the study site as a whole was determined by using the average density of all plots within the site.

Mature plant communities in each study site were measured for foliage density once between May and July. Plant communities undergoing succession were measured each year at the beginning and at the end of the growing season to quantify growth changes. These data were extrapolated for all seasons under the rationale that measurements involving leaves in the summer correspond to potentially leaf-bearing parts in the winter. Thus a community with dense leaves in summer should have more leaf-bearing parts in winter than a community that possessed few leaves in the summer. This assumption was validated by field measurements in selected study sites.

Foliage Height Diversity

Foliage height diversity for each transect was computed using information theory (Shannon and Weaver 1949) where

$$H = -\Sigma_{n=1}^{s} p_i \log p_i.$$

In this instance H equals foliage height diversity, and p_i equals the proportion of the

total foliage volume contributed by the volume at height level i.

Litter Height Diversity

Litter height diversity (LHD) was measured every 100 feet along the center line in each study site where litter was present in the trees. The measurement consisted of recording the presence or absence of litter within a 1.5 m radius at height intervals similar to those used in foliage volume measurements. Information theory was also used in calculating this parameter; p_i was the proportion of the total points with litter occurring in the ith layer.

In some vegetative types it was theorized that the amount and distribution of leaf litter above the ground was partly responsible for high rodent populations. Litter may provide additional nest sites, foraging substrate, or cover for some rodent species and even some birds and allow higher population numbers.

Phenology

Phenological data were recorded monthly for trees located in study sites. The objective was to record information which might explain population movements or trends within the mammalian and avian communities. Types of data gathered included duration and initiation of flowering, initiation and amount of stem growth, and fruit production.

Vegetative Communities

The various plant associations within the riparian habitat were classified as being components of six communities. These communities are listed in Table 1 along with the criteria used to distinguish each. The dominant tree species (total numbers) in some communities classified as cottonwood-willow was neither cottonwood nor willow, yet one or both of these species were responsible for the presence of one or more additional canopy layers to which the numerically dominant tree species did not contribute. If mature cottonwoods or willows were in densities of 2 or more per ha, the avian data indicated they exerted enough influence in the study site to be classified as cottonwood-willow.

Structural Types

Foliage density in the combined height intervals of 0.15 to 0.6 m, 1.5 to 3.0 m and >4.6 m was used in computing the amount of overlap in foliage density and structure between all pairs of study sites using Horn's (1966) formula where:

$$R_o = \frac{\Sigma(x_i+y_i)\log(x_i+y_i)-\Sigma x_i \log x_i-\Sigma y_i \log y_i}{(X+Y)\log(X+Y)-X\log X-Y\log Y}.$$

For study sites x and y, x_i and y_i represent the proportion of the volume occurring at height interval i, and X and Y represent the total foliage volume. From a matrix of these overlap values a dendrogram was constructed (fig. 1) showing study sites with greatest affinities between foliage density and structure. The dendrogram was constructed following Cody (1974) where

$$\alpha C,\ AB = \frac{\alpha C\ A + \alpha C\ B}{2}.$$

This simply states that the overlap of C with A and B is equal to the average of the overlap of C with A and C with B. The dendrogram was interpreted as showing the existence of six structural types of vegetation within the riparian habitat. Each study site within a structural type is more closely related in structure to the other members of that type than to any other site or group of sites.

Structural types I and II are the most heterogeneous, but as a group, they are separated by a substantial number of units from any other structural type.

Structural type I was the most dense overall and was characterized by the amount of volume over 9 m (fig. 2) although there were relatively well developed layers below the 9 m level. Type II was characterized by having less vegetation above 9 m but more volume between 3.0 and 6.0 m than type I. The other types were mainly characterized by having less volume at higher layers and more at 0.0 to 0.6 m (fig. 2).

RODENT POPULATION DATA

Small mammal populations were sampled by snap-trapping. We used two parallel rows of trap stations. One row was placed along the line of the sample site, and the second row was placed at a lateral distance of 15 m. Each row consisted of 15 stations, each station being 15 m apart. Two museum specials and one Victor rat trap were set at each station yielding a total of 90 traps. All traps were set for three consecutive nights using an oatmeal-peanut butter bait which contained an ant repellant (Anderson and Ohmart 1977). Traps were checked daily and the catch recorded. All mammal densities are expressed

Table 1.--Vegetative communities and criteria used to classify study sites within a community.

Community	Criteria
I. Cottonwood (*Populus fremontii*) Willow (*Salix gooddingii*)	*Populus* and/or *Salix* constituting at least 20% of the total trees
II. Screwbean mesquite (*Prosopis pubescens*) Salt cedar (*Tamarix chinensis*)	*P. pubescens* constituting at least 20% of trees
III. Honey mesquite (*Prosopis velutina*) Salt cedar	Approximately equal numbers of each
IV. Salt cedar	Constituting 95-100% of total trees
V. Honey mesquite	Constituting 95-100% of total trees
VI. Arrowweed (*Tessaria sericea*)	Constituting 95-100% of total vegetation in area

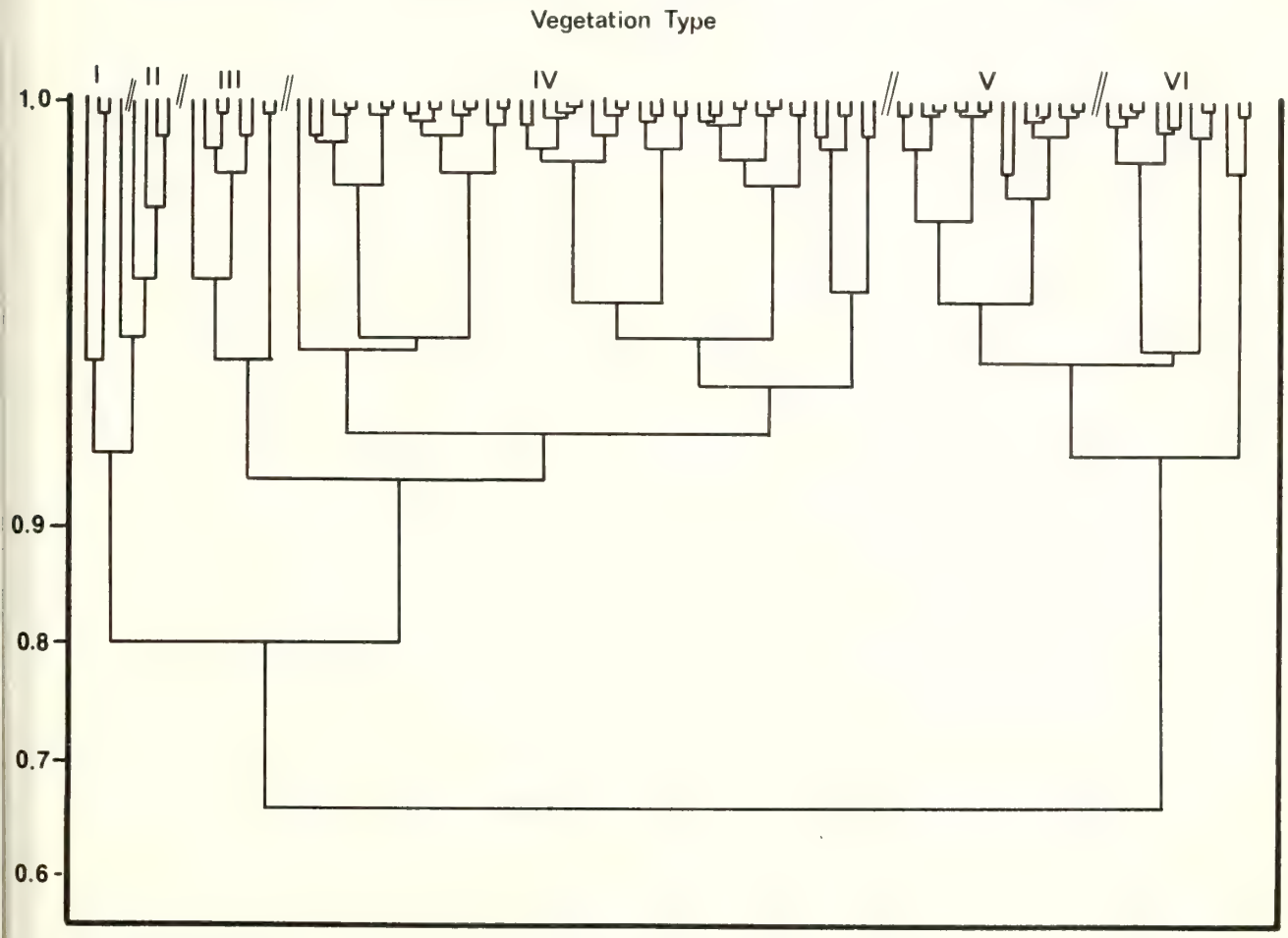


Figure 1.--Dendrogram showing relationships between all transects based on overlap in foliage density and structure.

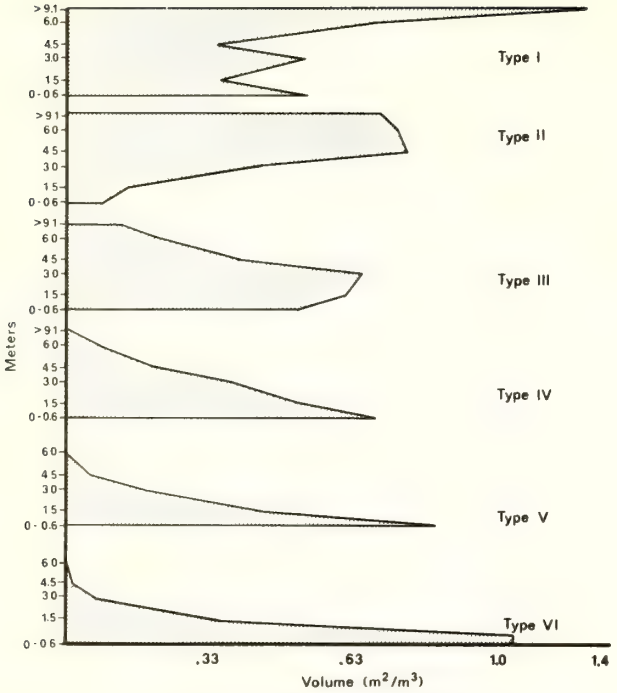


Figure 2.--Foliage volume characteristics of structural types.

as the number per 270 trap nights. No area was trapped consecutively within a six-week period.

Trapping of small mammals was organized so that all structural types represented within a community were sampled on an equal basis. Even with 60,000 trap nights in 1976, the data were not sufficiently adequate to examine some populations for more than two seasons, April through October and November through March. Any analyses utilizing finer divisions of time suffered from inadequate sample sizes for several species.

Standard reproductive measurements were recorded on all mammals to examine possible differential breeding rates and timing between communities. Cheek pouch contents were saved from all heteromyids for later analysis.

In an effort to better understand preferences of small mammals for particular microhabitat types, the vegetation present at three levels around each trap station was recorded. Species caught at a particular trap station could then be correlated with the vegetation around that station.

Rodent Species Diversity

Rodent species diversity for all community and structural types was computed using information theory where p_i is the proportion of the total density per 270 trap nights contributed by species i.

AVIAN POPULATION PARAMETERS

Avian Densities

Estimates of avian densities in each study site were calculated using a technique developed by Emlen (1971). Bird detections were recorded as being within 0 to 15, 15 to 30, and 30 to 60 m lateral distance from the study site center line. At the termination of each census of a study site the distribution of detection points for each species was used to determine the density per sampled area. All densities were converted to the number of individuals per species per 40 ha. Each study site was censused two to three times per month, and the mean was used as a monthly population estimate for each site. The number of censuses required per unit of plant community is discussed elsewhere in these proceedings (Anderson and Ohmart[3]/). In addition, mean monthly densities for each structural type in each community type allows analysis of seasonal changes in number of individuals and species composition.

As part of the regular census, bird detections were also recorded in the specific plot in which they occurred (fig. 3). This refinement was not necessary to obtain density estimates but served to document preferred vegetation profiles of each species as discussed later in the text.

Bird Species Diversity

Bird species diversity (BSD) was determined using information theory where p_i is the proportion of the total bird density contributed by the ith species. BSD's are calculated over a monthly and seasonal basis for each study site as well as for each structural type in each community.

Foraging Behavior

Foraging behavior of birds was recorded in all study sites to better understand the foraging niche of each species and to determine how each species utilized specific parts of its environment. By gathering these data in specific study sites, it was possible to compare foraging behavior to the structure, density, and vegetative species composition of the sites. Much of the behavior was gathered while conducting

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3/ Climatological and Physical Characteristics Affecting Avian Population Estimates in Southwest Riparian Communities using Transect Counts.

READ North TO South Colorado River BIRD DATA 06504 PAGE 1 OF 1

TRAN Pv10 DATE 10 May '77 TIME 0600-0715 CLOUDS Clear WIND Calm TEMP 60 F READER DGW

SPECIES	INT. m	DIRECTION: East 0-15m	15-30m	30-60	60-120	DIRECTION: West 0-15m	15-30m	30-60	60-120	BIRD HT	TREE HT	TREE SP	POS
Verdin	0-150							1					
Mourning Dove		1				1							
Abert's Towhee			2										
Cactus Wren	150-300		1										
Verdin							1						
Gambel's Quail				4									
Lucy's Warbler			1										

Figure 3.--Sample bird census form showing location of detection points within plots and at lateral intervals.

regular censuses. Specific parameters recorded for each species included:

Climatic conditions
Bird species and sex
Foraging method
Substrate
Height of substrate
Height of bird
Branch diameter
Location within tree
Shade or exposed

APPLICABILITY OF DATA

Data obtained in this study provide information concerning the extent of wildlife use in each of the various plant communities. Statistical analysis of many plant communities over a relatively large area permits examination of some of the factors responsible for these use values--be they specific vegetational configurations or the presence or absence of an ecologically close species. Through a comparison of species compositions and densities between community types and structural groupings, insight is gained into particular aspects of community ecology. A greater understanding of these relationships is necessary for management decisions. Specific examples are given below of ways in which these data may be examined in order to satisfy the outlined objectives. The analyses do not exhaust the list of possibilities but are primary ones found to be useful in this particular study.

Wildlife Use

The various avian and rodent population parameters and the vegetational parameters with which they are associated are as follows:

Avian Population Parameters
- Bird species diversity
- Number of species
- Bird density (total and by individual species)

Rodent Population Parameters
- Rodent species diversity
- Rodent density (total and by individual species)

Vegetation Parameters
- Foliage volume (total and by height classes)
- Foliage height diversity
- Tree counts (of a species by height class)
- Litter height diversity

Each comparison can be made on the basis of different area and time units. The possible units include:

Area Units
- Individual transects
- Communities
- Structural types
- Total riparian habitat

Time
- Individual months
- Seasons
- Different years

The specific ones chosen are dependent upon the specific needs and requirements of the study. We have found analyses of data by groups of months or seasons to be practical in determining wildlife use values, but we also utilize data

from individual months in certain analyses where more precise resolution is needed.

In examining wildlife use values one begins to see not only which species utilize an area, but also what factors in that environment have an important influence or at least show strong correlations with the various population parameters. Figure 4 presents correlation coefficients between several rodent populations and vegetational parameters in a honey mesquite community. It can be seen (fig. 4) that there is generally an inverse relationship between rodent density and rodent species diversity. One can predict that in an area with dense foliage at 1.5 to 3.0 m the rodent density would be relatively high, whereas the rodent species diversity would be depressed. This example only serves to show a small part of the total picture, but the implications in this case are evident concerning possible options to achieve the desired management goals.

Habitat Breadth

Habitat breadth values indicate the extent to which a species' population is evenly distributed throughout the habitat. It can be calculated using a species' distribution among the six categories of dominant vegetation and six structural types separately or combined. Habitat breadths are calculated on a monthly and seasonal basis. Since we currently (May 1977) have about 100 study sites in riparian vegetation and since each site is censused about three times per month, monthly habitat breadths are based on about 300 censuses. On a seasonal basis this increases to 900 censuses for winter (December, January, February) and summer (May, June, July); and 600 censuses for spring (March, April), late summer (August, September), and fall (October, November). This allows monitoring of monthly and seasonal changes in habitat breadth of each species.

Habitat breadth for each species is calculated using information theory where p_i represents the proportion of a species' total population contributed by its density within a community or structural type i. When expressed as the percent of maximum (J), habitat breadth can be used to designate species as generalists or specialists within communities or structural types. Any species with a percent value of maximum habitat breadth below an arbitrarily set limit would be classified as a specialist. It is possible for a species to be a specialist with regard to communities and a generalist with regard to structural types, and vice versa. Designating species as specialists or generalists is especially valuable to decision makers for management of critical habitats (i.e. those habitats containing several specialist species). It is these species which have the most exacting habitat requirements and which require special management efforts.

Niche Breadth

Niche breadth values are calculated in a manner similar to habitat breadth values but are based on the distribution of a species within a particular community. The proportion of the total community population of a species contributed by its density per individual study site in that community represents the p_i values in the information theory formula.

Calculation of niche breadth is an attempt at a more sensitive analysis of distribution of species within a portion of the habitat--the community. In combination with other measures of resource utilization, niche breadth is instructive in understanding the vegetational preferences of a species and how this changes through time and in comparison to other closely related species.

Preferred Vegetation Profiles

Using the data gathered on occurrence of birds within plots, it is possible to compute the preferred vegetation of each bird species. All bird detections within a plot located within a lateral distance of 15 m (0.2 ha) from the center line of the study site are compared to the vegetative characteristics of the plot in which the detection occurred. The 15 m lateral distance was selected because it was thought to be a complete census coverage of that area (i.e. all birds in that area were detected) and because it corresponded closely with the area of vegetation measurements, such as tree counts and foliage volume estimates. Given a suitable sample size of detections for each bird species, it is possible to calculate an average vegetation profile where a species is most often found. Collectively there are between 1,000 and 1,100 of these 0.2 ha areas. This profile will vary seasonally and will indicate the changing temporal requirements of a species. This can be done for all individuals of a species or during the breeding season for adult males only. The data can be further subdivided by dominant vegetation and/or structural types. These data are suitable for multivariate techniques such as discriminate function and principal component analyses.

Figure 5 (Anderson and Ohmart 1975) presents the preferred vegetation profiles of the Verdin (Auriparus flaviceps), Lucy's Warbler (Vermivora luciae), and Black-tailed Gnatcatcher (Polioptila melanura). Each is a small (<10 gm) insectivore with generally similar foraging behavior patterns. However, they each show a significantly ($p<0.05$) different preferred foliage profile. Lucy's Warblers generally inhabit the areas with

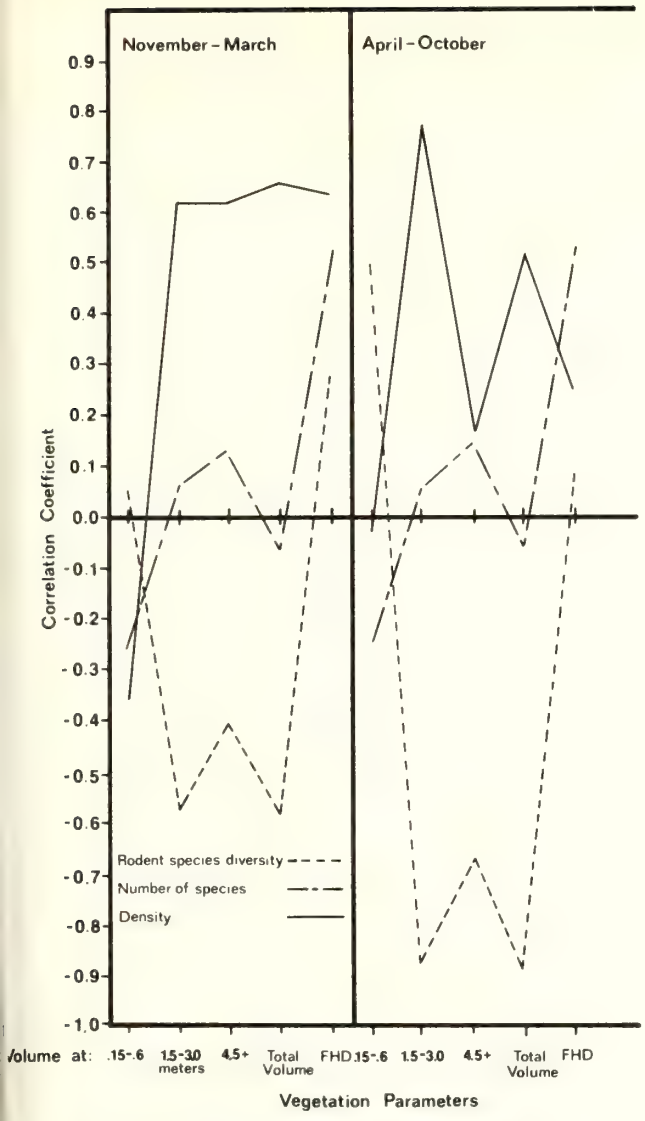


Figure 4.--Correlations between rodent population parameters and vegetation parameters in honey mesquite (Anderson and Ohmart 1975).

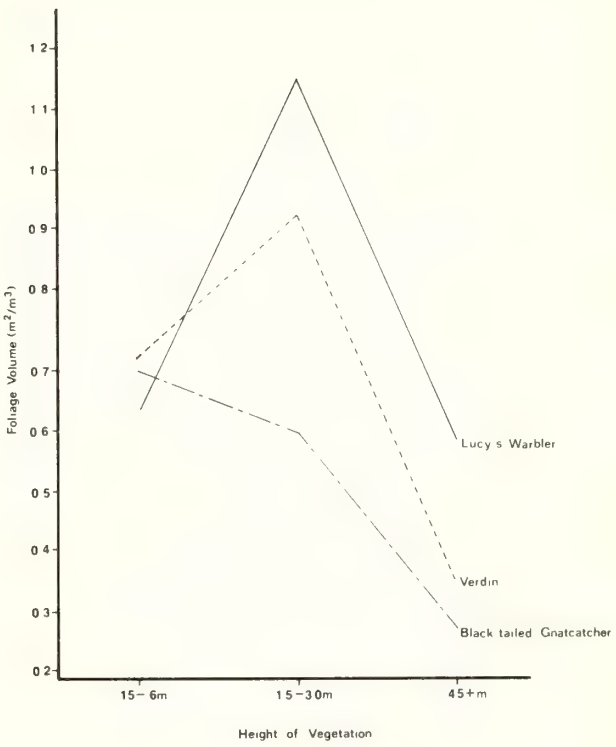


Figure 5.--Preferred structural configuration and foliage density of three bird species April through August 1975 (Anderson and Ohmart 1975).

denser vegetation at 1.5 to 3.0 m and the Black-tailed Gnatcatchers inhabit the sparser areas. These subtle divisions of the habitat are sometimes obscured by an analysis at the study site level due to the amount of heterogeneity within each site. By utilizing bird detections and vegetational measurements made within plots, some of the heterogeneity is reduced and more definite relationships can be observed.

Dispersal

We obtained a measure of the extent and time of dispersal in birds by calculating the average number of individuals of each species in each plot each month. The times of interspecific compatibility are indicated by the times of greatest average number per plot; dispersal is indicated when the average drops. These data are calculated monthly and are based on 1,000 to 1,100 plots.

Habitat and Horizontal Niche Overlap

Habitat and horizontal niche overlap are similar in that they compare the level of coexistence of two species within an area. As in the calculation of habitat breadths, habitat overlap can be calculated using two approaches to the composition of the habitat-i.e. community and structural types. Habitat overlap values are computed using Horn's formula (1966) for ecological overlap where x_i and y_i represent the density (per 40 ha for birds; number per 270 trap nights for rodents) in community or structural type i, and X and Y represent the sum of the x_i and y_i values.

Horizontal niche overlap values computed for birds only are based on the co-occurrence of species within plots. It is based on the ratio of the number of plots two species hold in common to the geometric mean of the number of plots they occupy separately as shown by Cody (1974) where:

$$H,12 = P_{12}/[(P_{11} + P_{12})\ (P_{22} + P_{12})]^{1/2}.$$

Here P_{12} equals the number of plots the two species hold in common and P_{11} and P_{22} represent the number of plots occupied by one species but not the other.

Overlap values, either habitat or niche, when organized into a matrix of species by species overlaps, can be used to construct a dendrogram (Cody 1974). A dendrogram illustrates those groups of species which are most similar to each other with respect to habitat or horizontal niche overlap. Figure 6 presents a simple dendrogram of horizontal niche overlap among the birds in salt cedar. The Mourning Dove (Zenaida macroura) and the White-winged Dove (Zenaida asiatica) are the only species with a high level of overlap. Each of these species obtains most of its food from agricultural areas (Anderson and Ohmart 1975). It is possible that the low overlap values exhibited among the other bird species may be due to the fact that salt cedar is an exotic plant to which the native avifauna has only partially adapted. Examination of overlap patterns within other communities as well as examination of patterns shown by other measures of resource utilization is necessary before any conclusions can be drawn.

Balda (1975) mentioned different approaches which have been used in the study of birds and their vegetative substrate. These approaches vary from intensive studies of single species to studies where assemblages of bird species were identified, counted and related to some component of the vegetative community. Each of these approaches has its advantages and disadvantages for the manager in a decision-making position. The techniques and procedures outlined above enable one to gather data which are in a versatile form. Pertinent information is available for a resource manager interested in managing for critical habitat of a rare species as well as for a theoretical ecologist exploring community organization patterns.

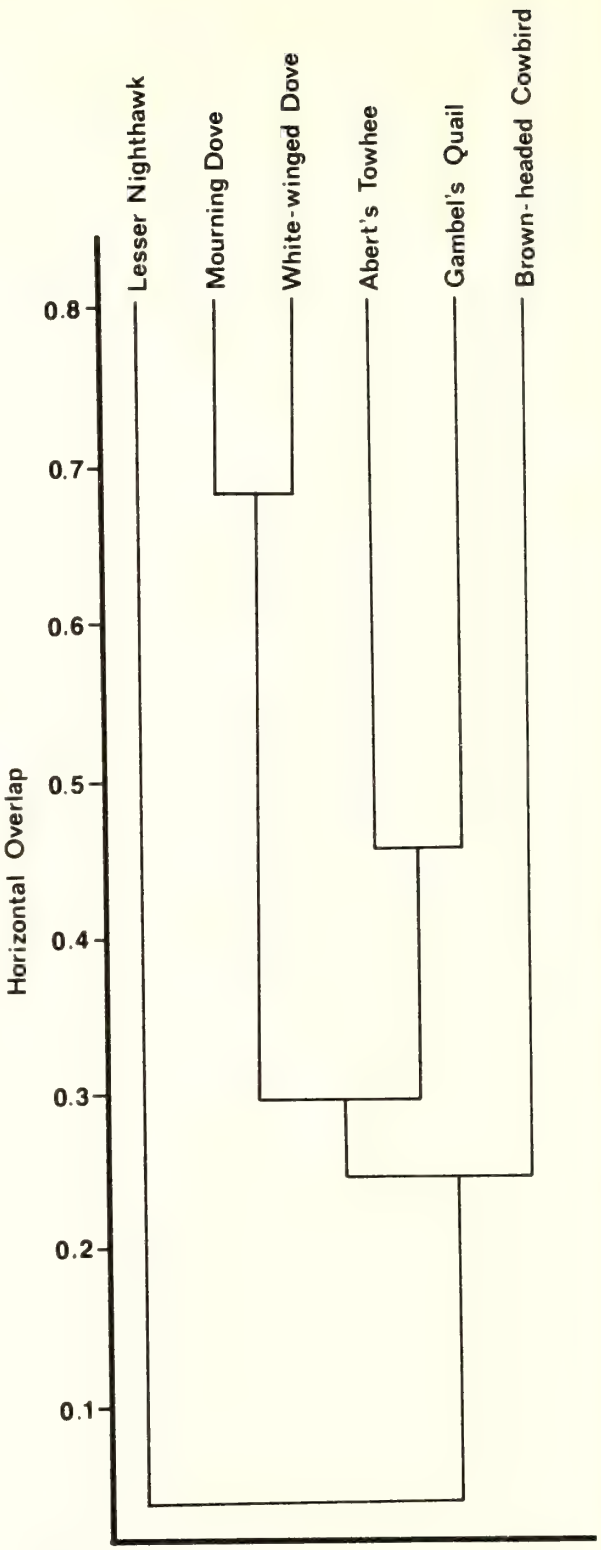


Figure 6.-- Horizontal niche overlap among birds in salt cedar April through August 1975 (Anderson and Ohmart 1975).

ACKNOWLEDGMENTS

We wish to thank the many field biologists who have helped us in collecting data. We are grateful to Jack Gildar for computerizing the data. The efforts of the secretarial staff

in typing early drafts and of Penny Dunlop and Katherine Hildebrandt in typing the final manuscript are greatly appreciated. We thank Jane Durham for editorial suggestions concerning the manuscript. Linda Cheney kindly prepared the illustrations. The research was funded through grant number 14-06-300-2415 from the U. S. Bureau of Reclamation.

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The Importance of Riparian Habitat to Migrating Birds[1]

Lawrence E. Stevens[2], Bryan T. Brown[3], James M. Simpson[4], and R. Roy Johnson [5]

Abstract.--Seven pairs of study sites in riparian and adjacent, nonriparian habitats were censused for spring migrant passerines. Riparian plots contained up to 10.6 times the number of migrants per hectare found on adjacent, nonriparian plots. Stop-over habitat selection is indicated by differing migrant densities and species diversities in various habitats. Passerine migration strategies are discussed.

INTRODUCTION

Field investigators have long noted that migrating passerines show a decided preference for riparian habitats over nonriparian habitats; however, virtually no data have been published concerning the nature of this preference. Riparian habitats provide an important source of food and cover for migrants and these habitats are being eliminated at such an alarming rate that the damage to migrant populations may be significant. The aim of this paper is to illustrate the importance of stop-over riparian habitats to migrant passerines in the Southwest. Only a few aspects of migration of western passerines are mentioned here but it is hoped that the data presented will stimulate additional research in this important field.

Many researchers have contributed to our knowledge of the timing of migration in southwestern passerines (Phillips 1951, Phillips et al. 1964, Hubbard 1971, Johnson and Simpson 1971, and others), but as yet no large-scale synthesis of migration patterns has been attempted. A growing concern for improved riparian habitat management practices has provided the impetus for a number of studies on riparian habitats by various government agencies (Johnson et al. 1974[6], Carothers and Johnson 1975, Lacey et al. 1975, Smith 1975, Carothers et al. 1976, Pace 1977[7], and others). Nearly all studies to date have ignored migrant passerines and their relationships to stop-over habitats in the Southwest (Sprunt 1975).

Migration, as Emlen (1975) indicated, is a multifaceted phenomenon. Some aspects of vernal (spring) migration related to stop-over habitat selection include migratory strategy, the influence of weather, and the development of migration routes. Literature for eastern North America indicates that passerines generally migrate nocturnally, resting and foraging during the day (Helms 1959, Able 1970, Welty 1975, and others). Gauthreaux (1972) suggested that vernal migrant passerines generally fly singly or in small, unispecific flocks. Vernal nocturnal migration in land passerines has been correlated with atmospheric stability and wind direction (Raynor 1956). Pleistocene speciation of Parulidae was discussed by Mengel (1964) and contemporary continental migration patterns were reviewed by Dorst (1962).

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7/ Pace, C.P. 1977. Classification, restoration and management of riparian habitats in southwestern forests. Rocky Mountain Forest and Range Experiment Station Study Plan 1710-44. Tempe. Unpublished, 44 pp.

Parnell's (1969) investigation of habitat selection in migrant eastern Parulidae (the North American wood warblers) demonstrated some correlation between warbler species and the stop-over habitat-niche chosen. Unexpectedly, he could not clearly demonstrate selection of major habitat types by migrant warblers in eastern forests.

METHODS

During the spring of 1977 a total of seven pairs of study areas were censused to determine migrant passerine densities and migrant diversities in stop-over habitats. The study sites, ranging in size from 1.6 hectares to 20.0 hectares, were located throughout Arizona. One site of each pair was situated in mature, riparian growth and the other in adjacent, nonriparian growth. Four pairs of study plots, those being used in the Rocky Mountain Forest and Range Experiment Station (RMFRES) riparian habitats study program, were examined in greater depth using the spot-map method (Williams 1936, Kendeigh 1944, and Franzreb 1976). The remaining three pairs of study sites were censused using a modified Emlen (1971) transect technique wherein an absolute count of birds was made. Data on the vegetation of the four paired RMFRES sites were gathered using the plotless point-quarter method of Cottam and Curtis (1956) and are included in Table 1. Tree heights were measured with a clinometer.

In addition, observation data on the spring migration of paulids for the Blue Point cottonwood stand was gathered from 1969 through 1974.

STUDY SITE DESCRIPTIONS

Terminology follows that of Hubbard (1971) with modifications. Study site sizes are included parenthetically.

1. Wet Beaver Creek (WBC) - Sullivan Ranch near Camp Verde, Yavapai Co., elev. 1250 m. A heterogeneous riparian forest with Platanus-Fraxinus overstory (4.1 hectares).

   Wet Beaver Creek Adjacent (WBCA) - a mixed microphyll (valley and slope mesquite)-evergreen woodland of Prosopis, Juniperus and Canotia (3.0 hectares).

2. Ash Creek (AC) - Rincon Mountains, Coronado Forest, Pima Co., elev. 1200 m. A heavily grazed heterogenous riparian woodland of Prosopis, Fraxinus and Celtis (4.1 hectares).

   Ash Creek Adjacent (ACA) - A heavily grazed, mixed microphyll (valley and slope mesquite)-evergreen-xeric shrubland of Prosopis, Mimosa, Quercus and Fouquieria (20.0 hectares).

3. Rucker Canyon (RC) - Chiricahua Mountains, Coronado National Forest, Cochise Co., elev. ca. 1600 m. A heterogenous, mixed riparian and evergreen forest with Quercus-Platanus overstory (5.0 hectares).

Table 1.--Vegetation of four RMFRES study sites

STUDY SITE	TREE SPECIES COMPOSITION	# TREES /HA	AVERAGE HT.TREES (METERS)	SHRUB SPECIES COMPOSITION	# SHRUBS /HA	AVERAGE HT.SHRUBS (METERS)
WBC	Platanus (25%) Juniperus (21%) Fraxinus (20%)	193	13.8	Mimosa (19%) Fraxinus (18%) Rubus (17%)	489	1.8
WBCA	Juniperus (68%) Prosopis (19%)	54	3.2	Canotia (28%) Juniperus (19%) Prosopis (17%)	1290	1.1
AC	Prosopis (52%) Fraxinus (23%) Celtis (17%)	124	5.3	Mimosa (41%) Baccharis (25%)	1510	0.9
ACA	Prosopis (86%) Quercus (14%)	59.3	3.6	Mimosa (44%) Gutierrezia (20%)	2638.5	0.8
RC	Juniperus (45%) Platanus (20%) Quercus (20%)	142	9.3	Rhus (43%) Juniperus (23%)	476	1.4
RCA	Quercus (61%) Juniperus (34%)	228	5.0	Rhus (36%) Nolina (33%)	691	1.3
TC	Juglans (31%) Prosopis (28%) Platanus (26%)	121	11.1	Juglans (48%) Prosopis (13%) Mimosa (12%)	490	1.6
TCA	Prosopis (33%) Quercus (32%)	29.4	4.4	Arctostaphylos (36%) Mimosa (27%) Prosopis (11%)	809	1.5

Rucker Canyon Adjacent (RCA) - a heavily grazed evergreen woodland of Quercus and Juniperus (6.0 hectares).

4. Turkey Creek (TC) - Rincon Mountains, Cornado National Forest, Pima Co., elev. 1250 m. A grazed homogeneous riparian forest with Platanus-Fraxinus overstory (5.9 hectares).

Turkey Creek Adjacent (TCA) - A grazed, mixed microphyll (slope mesquite)-evergreen shrubland of Prosopis, Quercus and Arctostaphylos (11.4 hectares).

5. Watson Lake (WL) - Near Prescott, Yavapai Co., elev. 1600 m. A homogeneous riparian forest with Populus-Salix overstory (7.5 hectares).

Watson Lake Adjacent (WLA) - A grazed, xeric grassland (7.1 hectares).

6. Blue Point (BP) - On the Salt River near Fort McDowell, Maricopa Co., elev. 400 m. A grazed, homogeneous riparian forest-woodland of Populus and Prosopis (10 hectares).

Blue Point Adjacent (BPA) - A grazed, xeric shrubland Cercidium association (10 hectares).

7. Indian Gardens (IG) - Grand Canyon National Park, Coconino Co., elev. 1150 m. An island of homogeneous riparian forest with Populus overstory (1.6 hectares).

Indian Gardens Adjacent (IGA) - A xeric, Coleogyne shrubland association (1.6 hectares).

RESULTS AND DISCUSSION

Tables 2, 3, and 4, and Figures 1 and 2 present the results of our 1977 spring migrant passerine survey. Residents and all possible breeding individuals and species were combined in the breeding bird category. This constitutes a significant overestimation of breeding bird populations and an underestimation of MPDen (migrant passerine density) and MPSD (migrant passerine species diversity) because some migrants were treated as breeding birds. Thus, in terms of migrants, these data are extremely conservative.

Table 2 presents the migrant species seen on the fourteen study plots. Note the generally higher MPSD of insectivores and the uniformly higher total MPSD on the riparian plots.

Table 3 and Figure 1 present MPDen data. The total number of migrant individuals in riparian habitats is shown to be uniformly greater (by up to 10.6 times) than the total number in adjacent, nonriparian habitats, with one exception. The open understory on the Turkey Creek plot attracted large flocks of Chipping Sparrows (Spizella passerina) and White-crowned Sparrows (Zonotrichia leucophrys) from the surrounding grasslands. Table 4 and Figure 2 show that the MPSD on all riparian study areas was distinctly higher than the MPSD on adjacent plots.

Other trends in these data can be observed. As in Table 2 insectivorous migrants generally preferred riparian habitats (WBC, TC, IG) and a higher insectivorous MPSD was also evident in most of those habitats. The larger number of granivorous individuals and smaller species diversity (WBCA, AC, TCA) of this group is an indication of flocking behavior in Fringillidae (the Finches, Sparrows and their allies). Granivores displayed habitat selection by avoiding dense riparian forest and woodland situations (WBC, BP); they tended to concentrate in adjacent shrublands (WBCA, WLA) and open, riparian forests (TC, IG). The importance of riparian habitats to breeding birds is also shown; in general, at least twice as many breeding individuals and species occurred in the riparian plots as did on the nonriparian plots.

Figures 1 and 2 illustrate differences in migrant use of heterogeneous and homogeneous habitats. Heterogeneous deciduous riparian habitats (WBC, AC) had generally higher MPDen and higher MPSD than did uniform stands of riparian growth (TC, WL, BP). Mixed riparian and evergreen forest habitats (RC) had lower MPDen and MPSD. Heterogeneous deciduous vegetation offers the greatest variety of habitat-niches for migrants, thus it is not unreasonable to expect substantial migrant use of these habitats. While uniform stands of riparian growth may be expected to support a lower MPSD the extremely low numbers on the Blue Point plot reflect inadequate sampling and poor weather conditions. Inaccessibility to migrants may account, in part, for the limited usage of the Rucker Canyon study area. Able (1970) has shown that 75% of eastern passerines migrate below an altitude of 920 meters and the same is probably true in the Southwest. A narrow canyon at a higher elevation may not be used by many migrants simply because the birds fly between mountain ranges rather than over them.

Moderately high MPDen and MPSD occurred in the only island stand of riparian vegetation studied (IG). It is not surprising that high MPDen and MPSD were found in riparian islands because these situations provide the only available food and cover for passage birds. The high percentage of granivores may reflect differences in migration patterns between fringillids and the insectivorous passerines.

Adjacent habitat depauperacy promotes a higher concentration of migrants in riparian habitats. Adjacent, nonriparian habitats which were not heavily grazed (WBCA and, to a lesser extent, TCA) supported a higher MPDen and MPSD than did those areas which were more heavily grazed (ACA, RC, WLA).

Patterns of migration in the Southwest have not been explored in depth. We observed only one wave migration of parulids in a five-year study of the Blue Point cottonwood stand; this concurs with Parnell's (1969) observation that wave migration is quite uncommon in eastern North American parulids. More frequently, though still not commonly, we have observed wide fronts of single species of parulids and fringillids. Most spring migration through the Southwest probably occurs in small, unispecific flocks,

Table 2.--Migrant passerine species occurrence and number of censuses per plot

	Paired (riparian and nonriparian habitats) study sites[1]													
	Heterogeneous						Homogeneous						Island	
MIGRANT PASSERINE SPECIES	WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Empidonax spp.	X	X	X	X	X	X	X	X			X			
Western Wood Pewee (Contopus sordidulus)											X			
Olive-sided Flycatcher (Nuttalornis borealis)			X											
Mountain Chickadee (Parus gambeli)					X								X	
Hermit Thrush (Catharus guttata)											X			
Western Bluebird (Sialia mexicana)			X											
Blue-gray Gnatcatcher (Polioptila caerulea)					X									
Ruby-crowned Kinglet (Regulus calendula)			X		X			X						
Cedar Waxwing (Bombycilla cedrorum)					X									
Solitary Vireo (Vireo solitarius)	X	X									X			
Warbling Vireo (Vireo gilvus)	X	X	X		X	X	X		X					
Virginia's Warbler (Vermivora virginiae)	X	X												
Lucy's Warbler (Vermivora luciae)					X									
Yellow-rumped Warbler (Dendroica coronata)	X	X	X	X	X	X	X	X	X				X	
Black-throated Gray Warbler (D. nigrescens)	X		X				X							
Townsend's Warbler (D. townsendi)							X				X			
Hermit Warbler (D. occidentalis)											X			

Table 2.--continued

MIGRANT PASSERINE SPECIES	Paired (riparian and nonriparian habitats) study sites[1]													
	Heterogeneous						Homogeneous						Island	
	WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
MacGillivray's Warbler (Oporornis tolmiei)				X					X					
Wilson's Warbler (Wilsonia pusilla)	X		X	X	X		X	X			X			
Western Tanager (Piranga ludoviciana)	X		X	X	X		X				X			
Black-headed Grosbeak * (Pheuticus melanocephalus)	X		X						X		X			
Lazuli Bunting (Passerina amoena)					X		X							
Pine Siskin (Carduelis pinus)	X												X	
Green-tailed Towhee (Pipilo chlorurus)		X	X	X				X	X					
Dark-eyed Junco (Junco hyemalis)			X			X								
Chipping Sparrow (Spizella passerina	X	X	X	X			X	X		X			X	
Brewer's Sparrow (Spizella breweri)										X				
White-crowned Sparrow (Zonotrichia leucophrys)									X				X	
Total # migratory insectivorous species	9	5	10	5	10	3	7	4	4	0	9	0	2	0
Total # migratory granivorous species	2	2	3	2	1	1	2	2	2	2	0	0	3	0
Total # migratory species	11	7	13	7	11	4	9	6	6	2	9	0	5	0
Total # breeding passerine species	18	11	19	11	14	12	20	23	15	8	14	6	10	2
Total # passerine species	28	18	32	18	25	16	29	29	21	10	23	6	15	2
Total # censuses/plot	1	1	2	2	3	3	3	3	1	2	2	1	2	2

* Insectivorous migrant species through Black-headed Grosbeak; granivorous migrant species below Black-headed Grosbeak.

1 Study sites are of varying sizes and are not comparable.

Table 3.--Spring migrant and breeding passerine densities in riparian and adjacent nonriparian habitats

		Heterogeneous						Homogeneous						Island	
		WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Average # migrant birds/ha	Insectivorous	34.7	5.0	4.3	0.3	1.7	0.3	3.4	0.8	4.1	0	1.5	0	1.8	0
	Granivorous	0.7	7.0	3.5	0.8	0.5	0.3	5.3	13.0	0.4	0.5	0	0	8.8	0
	Total	35.4	12.0	7.8	1.1	2.2	0.6	8.7	13.8	4.5	0.5	1.5	0	10.6	0
Average # breeding birds/ha *		12.4	7.7	11.1	2.9	8.4	3.8	18.0	7.0	6.1	0.6	7.0	0.4	9.9	1.3
Average total # birds/ha		47.8	19.7	18.9	4.0	10.6	4.4	26.7	20.8	10.6	1.1	8.5	0.4	20.5	1.3

* Including all potentially breeding passerine individuals

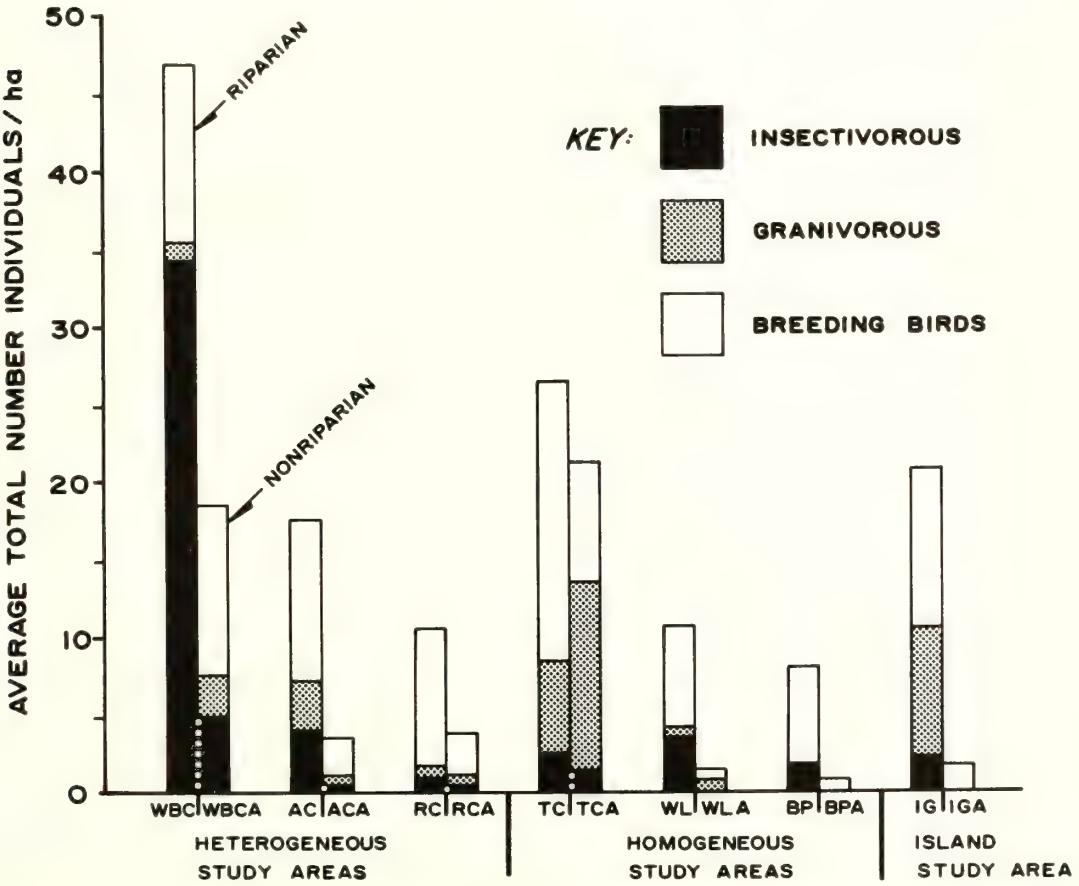


Figure 1.--Spring migrant and breeding passerine densities/ha in riparian and nonriparian habitats.

Table 4.--Spring migrant and breeding passerine species diversities/ha in riparian and adjacent, nonriparian habitats

		Heterogeneous						Homogeneous						Island	
		WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Average # migrant species/ha	Insectivorous	2.7	1.7	1.2	0.3	0.7	0.2	0.8	0.5	0.8	0	0.9	0	0.6	0
	Granivorous	0.2	0.7	0.4	0.1	0.2	0.1	0.2	0.2	0.3	0.1	0	0	1.6	0
	Total	2.9	2.4	1.6	0.4	0.9	0.3	1.0	0.7	1.1	0.1	0.9	0	2.2	0
Average # breeding species/ha *		4.4	3.7	2.3	1.0	2.7	1.2	2.9	2.1	2.6	0.4	1.4	0.5	6.2	1.3
Average total # species/ha		7.3	6.1	3.9	1.4	3.6	1.5	3.9	2.8	3.7	0.5	2.3	0.5	8.4	1.3

* Including all potentially breeding passerine species

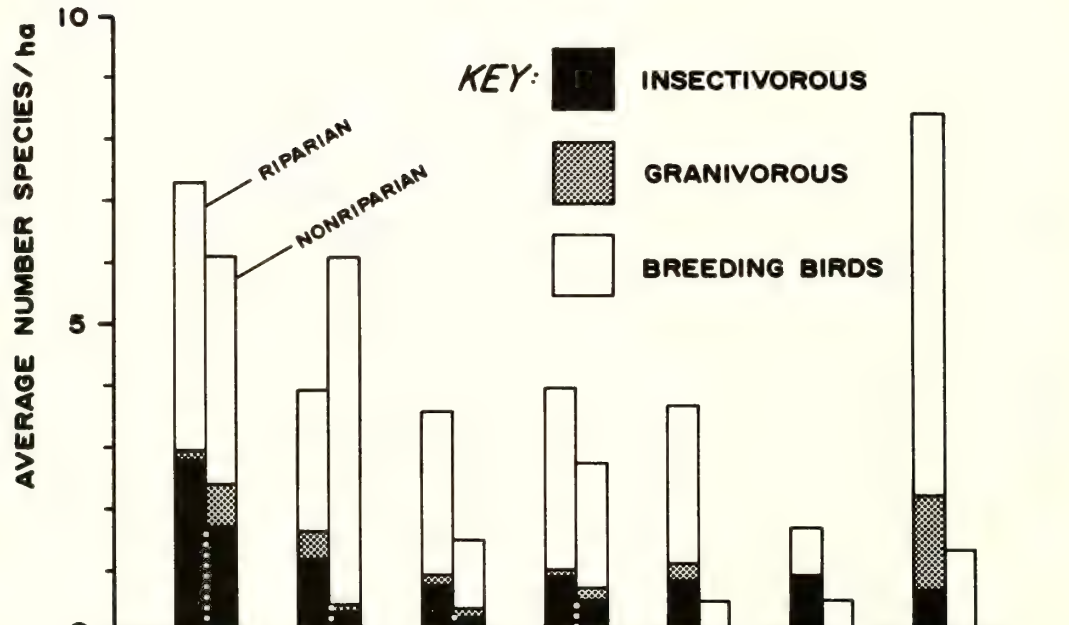


Figure 2.--Spring migrant and breeding passerine species diversities/ha in riparian and adjacent, nonriparian habitats.

as has been suggested by Gauthreaux (1972) for passerines migrating across the Gulf of Mexico.

CONCLUSIONS

From the data presented above it is evident that stop-over habitat selection by migrants occurs commonly in the Southwest. Riparian habitats support significantly higher MPDen and MPSD than do adjacent, nonriparian habitats. Insufficient data have been gathered as yet to substantiate the occurrence of niche selection, but the likelihood of this phenomenon is great. While Parnell (1969) could not clearly demonstrate habitat selection in migrant eastern warblers, habitat delineation is more distinct in the Southwest than in eastern deciduous and coniferous forests.

Parameters influencing migrant passerine use of riparian habitats include: specific habitat preferences of the bird (stop-over habitat selection); floral components (niche diversity and vegetational species composition); location of habitat (island situations and, perhaps, accessibility); and quality of the adjacent habitat (including the amount of grazing and other forms of impact).

The importance of riparian habitats to migrant passerines is substantial. Riparian habitat managers should consider the impact of proposed management not only on breeding species but also on migratory species. As Balda (1975) suggests, managers must be concerned with the quality of the avian populations they are indirectly managing through habitat manipulation. Riparian habitat management in vegetational islands and in heavily-grazed areas may have a greater effect on migrants and manipulation of these areas must be carefully evaluated.

ACKNOWLEDGMENTS

Part of the data presented here was gathered in conjunction with the Rocky Mountain Forest and Range Experiment Station, U.S. Dept. of Agriculture, Riparian Habitats Study Program Number 1710-44. We also thank the National Park Service at Grand Canyon National Park and the Museum of Northern Arizona for supporting this project. Special thanks go to S.W. Carothers, J.A. Downs, C.E. Franz, L.T. Haight, N.J. Sharber and K.W. Shoemaker for their assistance in gathering and compiling field data. We thank J. Scott for all her field and secretarial assistance.

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Significance of Rio Grande Riparian Systems Upon the Avifauna[1]

Roland H. Wauer[2]

ABSTRACT.--The Rio Grande corridor in West Texas serves as a significant migratory and emigration route for avifauna, and 38 species are known to nest within the riparian habitat. A total of 94 species are known to breed within riparian systems within the American Southwest. The Rio Grande area provides suitable habitat for 40% of those. Nine species--great blue and green herons, peregrine falcon, American kestrel, white-winged dove, screech owl, Bell's vireo, yellow warbler, and bronzed cowbird--are discussed as indicators of changes within the system and the important of the Rio Grande area as a refugium.

Few rivers on the North American continent stimulate the imagination as does the Rio Grande. It is that magical line that blends cultures and links natural environments from the highlands of the Rocky Mountains to the lowlands of the Chihuahuan Desert. It is a legendary river that joins, rather than separates, two countries. Both countries contribute to its flow and utilize its precious ingredients.

The Rio Grande begins in the mountains of Colorado and New Mexico, but little water is left by the time it reaches Texas. Irrigation and channelization claim a good deal of its cargo above El Paso. For another 100 miles below El Paso the once proud Rio Bravo del Norte, as it is known south of the border, is little more than a trickle. Below Presidio, Texas, however, the Rio Grande is rejuvenated by the Rio Conchos that brings water northward from the slopes of Mexico's Sierra Madre Occidental.

Tamayo (West, 1964) reported that the Rio Conchos supplies 18 percent of the Rio Grande's total flow, and that almost one-half of the Rio Grande's annual discharge is derived from Mexican tributaries. Since 1964 the flow of the Rio Conchos has been restricted by Granero Dam, and so an increasing amount of its water is utilized for irrigation in Mexico before reaching the Rio Grande influence. The least changed portion of the entire Rio Grande probably is within a strip of about 250 miles that lies between Colorado Canyon and Langtry, Texas. There the river makes a great southern swing into the Mexican states of Chihuahua and Coahuila. This paper is restricted to the riparian zone of that "Big Bend" area and eastward through Langtry to Amistad National Recreation Area.

Area Description

A satellite view of West Texas provides a realistic assessment of the contrast of the Rio Grande to its environment. The river appears like a green ribbon winding through a maze of grays, browns and blacks. This ribbon of greenery truly does meander its way through the arid desertscape of canyons, arroyos, and mesas. Elevations adjacent to the riverway range from 2,000 to 3,500 feet above sea level. A few mountains that are at least several miles from the river, such as the Chisos and del Carmens, may reach 7,800 feet elevation, but these have little influence upon the riparian zones along the riverway.

The general physiographic character of the Lower Canyons (an area from Big Bend National Park to near Langtry) of the Rio Grande was discussed by Johnson, et. al. (in press) in describing the vegetation found there. The zones include riverbed, riverbank, lower terrace or high floodplain, talus slope, canyon walls, side-canyon, and uplands or mesa-butte-rim. Although riparian vegetation does not

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exist in all of these zones, wildlife in each is influenced by the nearest riparian habitats. Wauer (in press) described the avifauna within each of the above seven zones. A good deal of the following material is taken from that publication and an earlier one by Wauer (1973), Birds of Big Bend National Park and Vicinity.

Riparian vegetation usually is considered to include that growing upon the floodplain and in adjacent arroyos, generally, wherever periodic flooding occurs. On the Rio Grande, riparian vegetation may extend from a few feet to one-half mile from the riverbed, except where sheer cliffs rise directly out of the river.

Common reed (Phragmites communis) and giant reed (Arundo donax) form tall "cane" stands along isolated or protected places and often hang out over the waterway. Other mesic forms that grow on the riverbank include lanceleaf cottonwood (Populus acuminata), honey mesquite (Prosopis juliflora), seepwillow (Baccharis glutonosa), the exotic salt cedar (Tamarisk sps.), and willows; the tall tree-willow is southwest black willow (Salix goodding ii), and black (S. niger) and sandbar willows (S. interior) are also present.

Just beyond this zone is another one that includes all the above plants and several others, including screwbean (Prosopis pubescens), catclaw acacia (Acacia greggii), black brush (A. rigidula), huisache (A. farnesiana), desertwillow (Chilopsis linearis), tree tobacco (Nicotiana glauca), common buttonbush (Cephalanthus occidentalis), and Texas palo verde (Cercidium texanum).

Ponds can be found in a few places where the Rio Grande has changed its course or where high water has dredged a deep hole. Seepwillow, salt cedar, and cowpen daisy (Verbesina encelioides), are early invaders of the silty soils. Common cattail (Typha latifolia), lanceleaf cottonwood, willows and Mexican devilweed (Aster spinosus) appear soon if there is sufficient moisture.

In places where the river regularly scours the rocky shoreline, a mat of Bermuda grass (Cynodom dactylon) may form a luxuriant cover. In protected flats within the lower canyons, extensive grassy vegas may result.

Riparian Avifauna of the Southwest

The American Southwest comprises a large and extremely diverse section of the United States. Elevations range from below sea level to over 12,000 feet, and environmental conditions vary from arid, desert lowlands to pine-clad forests. For the purpose of this discussion, the Southwest is the land mass north of the Mexican border between southeastern California (east of the Sierra Nevada foothills) and west Texas (west of Del Rio), north through the southern one-third of Utah and all of New Mexico but the northern highlands.

Two major river systems drain the Southwest, the Colorado River on the west and the Rio Grande on the east. Major tributaries include the Gila, Virgin, and San Juan on the Colorado, and the Rio Conchos, Pecos, and Devil's on the Rio Grande.

Table 1 includes 94 known avifauna that nest within riparian vegetation below the mountain woodlands and forests, below approximately 5,500 feet elevation. This list includes ground nesters and social parasites. It does not include species that nest in habitats that may be adjacent to riparian zones, such as peregrine falcon (Falco peregrinus) and cliff swallow (Petrochelidon pyrrhonota) that are cliff-nesters and common yellowthroat (Geothlypis trichas) and red-winged blackbird (Agelaius phoeniceus) that utilize swamps and marshes. It does include species such as American kestrel and great horned owl that usually nest on cliffs but have been found nesting on riparian vegetation.

Several earlier publications were utilized in developing the list of breeding avifauna. They include Death Valley National Monument, California, studies by Wauer (1962a, 1962b, and 1964), and Remsen's 1976 breeding bird survey near Needles, California, (1977); Nevada avifaunal summary by Linsdale (1936) and studies at Las Vegas (Austin, 1970) and the lower Virgin River (Wauer, 1969); Utah studies on the upper Virgin River (Wauer, 1967; Wauer, 1969), Zion National Park (Wauer and Carter, 1965); the Arizona summary by Phillips, Marshall, and Monson (1964); the New Mexico summary by Hubbard (1970); and west Texas studies in Big Bend National Park (Wauer, 1973), the Lower Canyons on the Rio Grande (Wauer, in press), and Amistad Recreation Area (LoBello, 1976).

Examination of the 94 riparian species indicates that only the mourning dove, verdin, northern oriole, brown-headed cowbird, and house finch occur within all nine riparian areas. Additional dominant species include ladder-backed woodpecker, ash-throated flycatcher, yellow-breasted chat, hooded oriole, and blue grosbeak--recorded for eight areas--and white-winged dove, black-chinned hummingbird, northern mockingbird, and Bell's vireo recorded for seven areas. Seventy-nine additional species were recorded on one to six of the areas, and only 13 species are listed only once: gray hawk in Arizona, California quail in Death Valley

TABLE 1 con't

Breeding Avifauna of Riparian Systems in Southwest U.S.

SPECIES[a]	SE Calif 1*	2	Nev 3	Utah 4	Ariz 5	NMex 6	W. Tex 7	8	9
Verdin (Auriparus flaviceps)	X	X	X	X	X	X	X	X	X
Bushtit (Psaltriparus minimus)			X	X					
White-breasted Nuthatch (Sitta carolinensis)					X	X			
House Wren (Troglodytes aedon)				X		X			
Bewick's Wren (Thryomanes bewickii)			X		X	X			
Carolina Wren (Thryothorus ludovicianus)								X	
Cactus Wren (Campylorhynchus brunneicapillus)			X		X	X	X	X	
Northern Mocking bird (Mimus polyglottos)	X		X		X	X	X	X	X
Gray Catbird (Dumetella carolinensis)					X	X			
Crissal Thrasher (Toxostoma dorsale)			X		X	X			
American Robin (Turdus migratorius)			X	X	X	X			
Western Bluebird (Sialia mexicana)			X		X	X			
Blue-gray Gnatcatcher (Polioptila caerulea)	X	X	X	X					
Black-tailed Gnatcatcher (Polioptila melanura)			X		X		X		
Phainopepla (Phinopepla nitens)		X	X	X	X	X		X	
Starling (Sturnus vulgaris)				X	X	X			
Bell's Vireo (Vireo bellii)			X	X	X	X	X	X	X
Solitary Vireo (Vireo solitarius)				X	X	X			
Warbling Vireo (Vireo gilvus)	X		X	X		X			
Lucy's Warbler (Vermivora luciae)	X		X	X	X	X			
Yellow Warbler (Dendroica petechia)	X		X	X	X	X	h	h	h
Yellow-breasted Chat (Icteria virens)	X		X	X	X	X	X	X	X
Orchard Oriole (Icterus spurius)						X	X	X	X
Hooded Oriole (Icterus cucullatus)	X	X	X		X	X	X	X	X
Northern Oriole (Icterus galbula)	X	X	X	X	X	X	X	X	X
Great-tailed Grackle (Quiscalus mexicanus)					X	X	X	X	X

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SPECIES[a]	SE Calif 1*	2	Nev 3	Utah 4	Ariz 5	NMex 6	W. Tex 7	8	9
Broad-billed Hummingbird (Cynanthus latirostris)					X	X			
Common Flicker (Colaptes auratus)				X	X	X			
Golden-fronted Woodpecker (Centurus aurifrons)							X		X
Gila Woodpecker (Centurus uropygialis)			X		X	X			
Lewis' Woodpecker (Melanerpes lewis)						X			
Hairy Woodpecker (Dendrocopos villosus)			X	X		X			
Downy Woodpecker (Dendrocopos pubescens)						X			
Ladder-backed Woodpecker (Dendrocopos scalaris)		X	X	X	X	X	X	X	X
Rose-throated Becard (Platypsaris aglaiae)					X				
Eastern Kingbird (Tyrannus tyrannus)						X			
Tropical Kingbird (Tyrannus melancholicus)					X				
Western Kingbird (Tyrannus verticalis)	X		X	X	X	X			p
Cassin's Kingbird (Tyrannus vociferans)							X		
Thick-billed Kingbird (Tyrannus crassirostris)					X	X			
Wied's Crested Flycatcher (Myiarchus tyrannulus)				X	X	X			
Ash-throated Flycatcher (Myiarchus cinerascens)		X	X	X	X	X	X	X	X
Olivaceous Flycatcher (Myiarchus tuberculifer)					X	X			
Willow Flycatcher (Empidonax traillii)			X	X	X	X	X		
Hammond's Flycatcher (Empidonax hammondii)						X			
Western Flycatcher (Empidonax difficilis)				X					
Western Wood Pewee (Contopus sordidulus)	X			X	X	X			
Vermilion Flycatcher (Pyrocephalus rubinus)			X	X	X	X	X	X	
Beardless Flycatcher (Camptostoma imberbe)					X	X			
Violet-green Swallow (Tachycineta thalassina)				X	X	X			
Black-billed Magpie (Pica pica)			X	h	h	X			
Black-capped Chickadee (Parus atricapillus)				X					

TABLE 1

Breeding Avifauna of Riparian Systems in Southwest U.S.

SPECIES[a]	SE Calif 1*	2	Nev 3	Utah 4	Ariz 5	NMex 6	W. Tex 7	8	9
Great Blue Heron (Ardea herodias)			X	X	X	X			
Green Heron (Butorides striatus)			X	X	X	X	h		p
Great Egret (Casmerodius albus)					X	X			
Snowy Egret (Egretta thula)					h	X			
Black-crowned Night Heron (Nycticorax nycticorax)					X	X			
Cooper's Hawk (Accipiter cooperii)				X	X	X			
Gray Hawk (Buteo nitidus)					X				
Black Hawk (Buteogallus anthracinus)				X	X	X			
American Kestrel (Falco sparverius)			X	X	X	X			
California Quail (Lophortyx californicus)	X								
Gambel's Quail (Lophortyx gambelii)	X	X	X		X	X			
White-winged Dove (Zenaida asiatica)			X	X	X	X	X	X	X
Mourning Dove (Zenaida macroura)	X	X	X	X	X	X	X	X	X
Common Ground Dove (Columbigna passerina)					X	X	X	X	X
Inca Dove (Scardafella inca)					X		X		X
Yellow-billed Cuckoo (Coccyzus americanus)	X			X	X	X	X	X	p
Greater Roadrunner (Geococcyx californianus)	X		X	X	X	X	X		
Common Screech Owl (Otus asio)			X	X	X	X	X	X	
Great Horned Owl (Budo virginianus)	X			X	X				
Ferruginous Owl (Glaucidium brasilianum)					X				
Elf Owl (Micrathene whitneyi)					X	X	X	X	
Long-eared Owl (Asio otus)			X	X	X				
Lesser Nighthawk (Chordeiles acutipennis)			X	X			X	X	p
Black-chinned Hummingbird (Archilochus alexandri)			X	X	X	X	X	X	X
Costa's Hummingbird (Calypte costae)		X	X		X				
Violet-crowned Hummingbird (Amazilia verticalis)					X	X			

TABLE 1 con't

Breeding Avifauna of Riparian Systems in Southwest U.S.

SPECIES[a]	SE Calif 1*	2	Nev 3	Utah 4	Ariz 5	NMex 6	W. Tex 7	8	9
Brown-headed Cowbird (Molothrus ater)	X	X	X	X	X	X	X	X	X
Bronzed Cowbird (Molothrus aeneus)					X	X	X		
Summer Tanager (Piranga rubra)			X	X	X	X	X	X	
Northern Cardinal (Cardinalis c.)					X	X	X	X	X
Black-headed Grosbeak (Pheucticus melanopephalus)		X		X	X	X			
Blue Grosbeak (Guiraca caerulea)	X	X		X	X	X	X	X	X
Indigo Bunting (Passerina cyanea)				X	X	X			
Lazuli Bunting (Passerina amoena)	X	X	X	X	X	X			
Painted Bunting (Passerina ciris)						X	X	X	X
House Finch (Carpodacus mexicanus)	X	X	X	X	X	X	X	X	X
American Goldfinch (Spinus tristis)	X		X						
Lesser Goldfinch (Spinus psaltria)	X	X	X	X		X			
Lawrence's Goldfinch (Spinus lawrencei)					X				
Rufous-sided Towhee (Pipilo erythrophthalmus)	X			X		X			
Abert's Towhee (Pipilo aberti)			X	X	X	X			
Song Sparrow (Melospiza melodia)			X	X	X	X			
TOTALS	24	16	47	51	69	75	33	27	20

a = names follow AOU (1957, 1976)
h = historical only
p = probable

*1 = Wauer, R.H., 1962a, 1962b, 1964
2 = Remsen, J.V., 1977
3 = Linsdale, J.M., 1936; Wauer, R.H., 1969; Austin, G.T., 1970
4 = Wauer, R.H., 1967; Wauer, R.H. and D.L. Cater, 1965
5 = Phillips, A., J. Marshall, G. Monson, 1964
6 = Hubbard, J.P., 1970
7 = Wauer, R.H., 1973
8 = Wauer, R.H., (in press)
9 = LoBello, R.L., 1976

(an introduced species there according to Wauer (1962)), ferruginous owl in Arizona, Lewis' and downy woodpeckers in New Mexico, rose-throated becard and tropical kingbird in Arizona, Cassin's kingbird in west Texas, eastern kingbird and Hammond's flycatcher in New Mexico, western flycatcher in Zion National Park, Utah, Carolina wren in the Lower Canyons of the Rio Grande, and Lawrence's goldfinch in southern Arizona.

Significance of Riparian Habitat in West Texas

Before roads, the Rio Grande corridor was the most sensible route of traveling through the harsh, arid environment. It provided a practical passageway between the Chihuahuan Desert region of west Texas and the semi-tropical Lower Valley. It was used by man and wildlife alike. Today, the Rio Grande route is left to wildlife and plants, to a few re-creationists, and those of us who need the "spirit of the river."

The Rio Grande still serves as migratory and emigration routes for plants and animals. Plant species washed away by high water from one place may be deposited in an appropriate place to take root many miles downriver. Down-river species may edge slowly along or be transferred distances by some natural agent. Extensions of western and eastern forms occur all along the Rio Grande waterway. This phenomena, as it pertains to the flora, is discussed by Johnson, et. al. (in press), but the natural parameters that restrict plant species, such as temperatures and soils, do not always apply to the more mobile avifauna.

Several breeding birds known to occur within the Texas Big Bend Country appear to owe their presence there to the river corridor. Good examples of breeding birds of the Rio Grande area with eastern affinities are orchard oriole, hooded oriole, and great-tailed grackle. Orchard oriole frequents deciduous environments throughout the eastern United States and its breeding range extends through west Texas to El Paso along the Rio Grande. Two races of hooded orioles breed within riparian zones along the lower Rio Grande. The nominant form occurs from near the eastern border of Big Bend National Park downriver to near Laredo (Oberholser, 1974). The breeding range of I.c. nelsoni extends westerly along the river in Texas through Big Bend National Park. The breeding race of great-tailed grackle (C.m. monsoni) extends only within the Trans-Pecos and along the Rio Grande to about Amistad Reservoir where C.m. prosopidicola occurs (Selander and Giller, 1961).

The Rio Grande corridor further explains the presence of a number of post-nesting birds that breed out of the area and wander into the area afterwards. The green kingfisher (Chloroceryle americana) breeds in central and southern Texas and disperses outward after the breeding season. Records exist along the Rio Grande to the west edge of the Big Bend National Park (Wauer, 1973; Oberholser, 1974). The great-crested flycatcher (Myiarchus crinitus), a species that nests throughout the eastern two-thirds of Texas (Oberholser, 1974), has been recorded only from August 24 through October 29 in Big Bend National Park (Wauer, 1973). The third example is the Carolina wren that breeds to the eastern edge of the area of concern, and all records west of Del Rio exist along the Rio Grande (Wauer, 1973; Oberholser, 1974).

The use of the Rio Grande corridor for a migratory route is one of the well recognized patterns of southwestern avian behavior. Wauer (1973) thoroughly discussed the spring and fall migration through Big Bend National Park, and much of that discussion applied to the rest of the lower Rio Grande area.

Although the characteristic of northbound and southbound bird movement along major waterways is common elsewhere, it is likely that a river corridor is more important to migrating birds in arid parts of the country than in humid, heavier vegetated areas. In west Texas, hot-dry desert conditions prevail during the principal portion of the spring and fall migration. Therefore, the availability of food, water, cover, and suitable north-south routing are exceptionally important and strongly influence migrants. A quantitative analysis of bird movement along the Rio Grande corridor is not available, although such a study would be extremely worthwhile.

The migration periods for Big Bend National Park were analyzed by Wauer (1973) who stated that "Fall migration in the lowlands is only a shadow of the spring movement." To understand the migration patterns for the avifauna it is necessary to point out that the area is split into two halves by a mountain range that runs north-south along the eastern side of Big Bend National Park. This range--the Sierra del Carmens--extends north of the Rio Grande for about 60 miles and south for about 100 miles. It results in a splitting of the northbound migrants so that the north-south valleys on both sides of the del Carmens are utilized. Fall migrants following the valleys southward are diverted along the northern boundary of the park by the Santiago Mountains (an extension of the Sierra del Carmens that continue northwesterly) toward the southeast and along the eastern side of the del Carmens. This

route is through the desert north of Persimmon Gap and into the Black Gap Wildlife Management Area and then into the Rio Grande canyons and riparian habitats. Southbound migrants undoubtedly find water and food within the lush riparian vegetation along the river that is more inviting than that in the adjacent desert landscapes.

The lower Rio Grande also is a refugium for nesting avifauna that rely upon the riparian systems. I have selected nine species to analyze: great blue heron, green heron, peregrine falcon, American kestrel, white-winged dove, screech owl, Bell's vireo, yellow warbler and bronzed cowbird.

Great blue heron and green heron are known to have nested within the riparian vegetation along the Rio Grande in historic times (Van Tyne and Sutton, 1937). Wauer (1973), reported that great blue herons are present in Big Bend National Park all year but no recent nesting. He stated that, "Today, between Boquillas and Presidio, there is only a single grove of cottonwoods and willows large enough to support a rookery; it is located on the floodplain near Santa Elena Crossing, where there probably is too much human activity for nesting herons." More recently, LoBello (1976), reported a nest containing four eggs, on Javelina Bluff near Rough Canyon Marina, Amistad Reservoir, April 26, 1975. The nest was located on a sheer cliff about 200 feet above the water. It is possible that this species can adapt to solitary nesting on cliffs within the Rio Grande canyons to continue its status as a breeding bird of the lower Rio Grande. It will undoubtedly continue to utilize the riparian vegetation for perching, cover, and finding food.

There are no known records of breeding green herons in recent years. I suspect that nesting does occur in out of the way places within the riparian zone. It is present throughout the summer months at Big Bend National Park (Wauer, 1973), and LoBello (1976) found it at Amistad Reservoir consistently in summer, including an immature bird on August 11. Riparian vegetation is essential to the survival of this heron for perching, roosting, and hunting. It is extremely unlikely that cliff-nesting is feasible for this species.

Peregrine falcon is an excellent tribute to the wilderness character of the Rio Grande canyons and the accessability of relatively non-polluted food. It nests on high canyon walls and hunts for food along the riverway. Mourning and white-winged doves, common nesting birds of the riparian habitat, provide sufficient food supplies for at least five pairs of this endangered species from Big Bend National Park to Amistad Reservoir (Wauer, 1973; Hunt, 1975).

Peregrines have declined drastically within the United States since the 1940's. The population east of the Mississippi River and south of the boreal forests was estimated at 400 pairs, and today not a single breeding wild pair remains. In the western United States the population is only ten percent of what it was in the 1940's. So, the Rio Grande canyons serve as a significant refugium for this highly endangered species. American kestrel is a common nesting bird along the Rio Grande canyons It is an adaptable species that obtains its food from many sources, including the riparian habitats within the Rio Grande corridor and adjacent arroyos. Also, I have found it numerous in migration, when up to half-dozen birds can be expected along a few miles of riparian habitats. The principal migration occurs from late September through November and mid-March through early May (Wauer, 1973).

White-winged dove is resident along the Rio Grande throughout the Big Bend area, and flocks at the more extensive riparian zones during winter; Wauer (1973) recorded 70 individuals at Rio Grande Village on January 22, 1970. Generally, white-winged dove populations have been severely depleted throughout much of their range in recent decades. In the Lower Valley of the Rio Grande, thousands of acres of land were cleared of native brushland during the 1940's and 1950's, and the white-winged population took a drastic nosedive. Since then, citrus trees have been planted and support nesting white-wings, although the population has not returned to what it was under natural conditions.

A combination of land clearing, land flooding by Falcon and Amistad Reservoirs, and the addition of increasing hunting pressures upon the white-winged dove populations in Mexico (several populations from the United States winter in Mexico) have had severe negative effects upon the Texas white-wings. The riparian zones within the Big Bend country provide some of the most stable known habitat.

Screech owl occurs within the riparian habitat along the river and adjacent arroyos and oases throughout the year. The Rio Grande corridor appears to provide habitat for extensions of ranges of two races that overlap within the Big Bend area. Marshall (1967) found hybridizing Otus asio suttoni and O.a. mccalli in the riparian vegetation near Rio Grande Village.

Bell's vireo may be regarded as the most numerous breeding bird within the Rio Grande riparian systems of west Texas. Its song is ubiquitous among the floodplain and arroyo vegetation from late March through early June. Two races breed within the area; the nominant form along the eastern edge, and V.b. medius through the Big Bend National Park area (AOU, 1957).

In Arizona, the species is "scarce and local in at least the Phoenix and Benson areas, this tiny bird was certainly decimated in the latter by cowbird parasitism" (Phillips, 1968). It is strange that the species is so abundant within the west Texas riparian systems in spite of the abundance of brown-headed cowbirds.

Yellow warbler is absent or a rare breeding bird of riparian zones within west Texas. This apparently was not the case during earlier years. Wauer (1973) stated that, "Van Tyne and Sutton reported that it nested at Boquillas, Hot Springs, and San Vicente during the 1930's, but I have searched the floodplain for nesting birds without success. In five years (1966-1971) I have found only three summertime birds." Allan Phillips (1964) believes that the species has been extirpated by parasitism of brown-headed cowbirds in some parts of southern Arizona, and this may well be the case in the Big Bend; cowbirds have increased in recent years and are now abundant along the river floodplain where yellow warblers once nested.

Bronzed cowbird has been a summer resident within the Big Bend National Park only since 1969 (Wauer, 1973). There were no summertime records of the species prior to 1969, but there are numerous records within the riparian zones since. These recent sightings include several cases of parasitism, principally on hooded and orchard orioles. These orioles are common within the riparian zones, but long-range analysis of their status should be undertaken to determine if the recent impacts pose significant threats to their populations.

Phillips (1968) states that the species was first seen in Arizona in 1909, but spread through the southern one-half of the state within 20 years. He suggests that additional spread was restricted by the species failure to find enough hooded oriole nests to parasitize. Based upon these comments, it is likely that the bronzed cowbird will readily spread throughout the Rio Grande at least north of El Paso where hooded orioles breed.

Summary

The significance of the Rio Grande riparian zones within west Texas can only be speculated upon, but evidence suggests that it is of major importance. Several avian species are present that are absent or rare elsewhere, and numerous species utilize the river corridor as routes through inhospitable habitat. So much of the riparian communities of the Southwest have been destroyed and changed in recent decades, that one that possesses natural characteristics must be given special protection. The importance of a relatively unchanged extensive riparian system becomes more significant daily.

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Some Effects of a Campground on Breeding Birds in Arizona[1]

Stewart W. Aitchison[2]/

Abstract.--Over a three year period, breeding bird densities were found to be similar between a constructed campground and a relatively natural area when the campground was closed to campers. However, bird species composition differed between sites, the campground having relatively heavier bodied birds ($\bar{x}$ = 48.5 g) than the control area ($\bar{x}$ = 38.2 g). Once the campground was opened for human use, the breeding bird population decreased in density and diversity. On the control site the population either remained the same or increased.

INTRODUCTION

It has been well documented that the human manipulation of Southwestern habitats greatly affects the configuration of the avian community that will continue to utilize the area (e.g., Carothers et al. 1974, Carothers and Johnson 1975). These studies have primarily concerned themselves with phreatophyte control, channelization, and other water management practices. Very little research has dealt with the impact caused by the construction of permanent structures and human occupation of these areas (e.g., subdivisions, trailer parks, and campgrounds). The present study examines the effects of a U.S. Forest Service improved campground upon breeding birds.

ACKNOWLEDGEMENTS

The author wishes to thank M.E. Theroux for collecting and processing the vegetation data, S.W. Carothers and O.J. Reichman for critically proofing the manuscript, and many other members of the Museum of Northern Arizona staff for their help and encouragement. Special thanks goes to B. Johnston who did nearly all the field work in 1974 and a substantial amount in 1975.

Financial support for this study was partially provided by the U.S. Forest Service, Coconino National Forest,and to this end I wish to thank B. Burbridge and W. Finley. Also, the Sedona Ranger District graciously allowed us to set up the two study plots in Oak Creek Canyon.

STUDY AREA

Two sites were chosen which appeared similar in vegetative structure, each being composed primarily of ponderosa pine with some cottonwood, Arizona walnut and other deciduous trees and shrubs. (Table 1 summarizes the vegetation analysis of the study areas.) Both sites are within Oak Creek Canyon, Sec. 27, T19N, R6E, Coconino County, Arizona, at an elevation of 1,646 m. One plot was located within the Cave Springs Campground; the other plot, control, was slightly north and across the Oak Creek.

The Cave Springs Campground study site is 4.0 ha. Extensive timber and shrub removal, construction of roads, pit toilets, and erection of tables has occurred here. The campground is open for public use from approximately Memorial Day to Labor Day of each year.

Control is approximately 2.0 ha. Relative to the campground, this area is undisturbed by human activities.

Though the two sites are small in area, thus making extrapolation of figures somewhat misleading, they encompass as much homogeneous habitat as possible. Further, the small size enabled the investigators to know the avian components intimately, and therefore we feel a very accurate count of species was achieved.

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[1]/ Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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Table 1.--Vegetation Analysis

Study Area		Tree Density Per Hectare	Basal Area (m^2) Per Hectare	Average Tree Height (m)
CAMPGROUND	Ponderosa Pine *Pinus Ponderosa*	437.1	2153.6	12.4
	*All other species	316.5	415.0	7.3
CONTROL	Ponderosa Pine	347.8	2118.4	14.0
	**All other species	1010.7	447.8	5.0

* *Acer negundo*, *Alnus oblongifolia*, *Juniperus scopulorum*, *Quercus gambelli*, *Populus lanceolata*, *Salix gooddingii*.

** *Acer negundo*, *Alnus oblongifolia*, *Fraxinus pennsylvanica* var. *velutina*, *Juniperus scopulorum*, *J. monosperma*, *Pinus edulis*, *Populus lanceolata*, *Quercus* spp.

METHODS

The populations of breeding birds were determined by the spot-map method (Williams 1936, Kendeigh 1944). On each census the location of singing males, song posts, and nest sites was recorded for each census and information on every species was later recorded onto species maps. Censusing was carried out from 4 April to 6 July 1973, 18 February to 1 July 1974, and 9 May to 10 July 1975; these periods included the entire observable breeding season. Densities were determined for each area before and after the date the campground was opened (e.g., 29 May 1973, 17 May 1974, and 16 May 1975). [Note: All densities were extrapolated to 40 ha to make inter-area comparisons easier.]

Foliage height diversity (FHD) was sampled along ten 100 m transects established at random throughout the study areas. Presence or absence of vegetation at 2 m intervals along the transects was noted at three layers chosen to approximate foliage stratification into herbaceous (0-0.6 m), shrub (0.6-4.49 m) and canopy ($\geq$4.5 m) layers. A 4.5 m rod marked at 0.6 m from one end was used to record the presence or absence of foliage for the herbaceous and shrub layers, and the ocular tube method (Winkworth and Goodall 1962) was used for the canopy layer. For recording the presence of vegetation in the herbaceous and shrub layers, it was necessary for green foliage to touch the vertically held rod.

All vegetative and avian diversity indices are computed as $H' = -\sum P_i \log_e P_i$ based on the Shannon-Wiener model of information theory (see Shannon and Weaver 1963) as it applies to biological parameters (MacArthur and MacArthur 1961; MacArthur 1965; Pielou 1966a,b; Lloyd et al. 1968).

Tree density, species composition and basal area were determined by the plotless point-quarter method of Cottam and Curtis (1956). Tree heights were determined by use of a clinometer. Samplings witha diameter at breast height (DBH) of less than 7.6 cm were treated as shrubs.

Avian standing crop biomass (SCB) was determined by taking the average adult weight (W) times the number of adults per unit area. Existence Energy (EE) or the amount of kcal consumed per ha per 24 hours was calculated from these two formulae:
Log EE = 0.3581 + 0.5876 Log W (for passerines)
Log EE = 0.0649 + 0.6722 Log W (for non-passerines).

These formulae give the energy requirements to maintain a constant weight at rest. To determine actual community energetics it would be necessary to include energy requirements of the immature birds, and the various energy demanding activities of breeding birds (e.g., singing, displaying, nest building). The limitations of this procedure notwithstanding, it is instructive to make inter- and intra-community comparisons with these low estimates of avian community energetics (see Karr 1968 and 1971).

RESULTS AND DISCUSSION

A total of 58 species (Table 2) of birds

Table 3.--Avian density and species richness

SPECIES	1973				1974				1975			
	CONTROL		CAMPGROUND		CONTROL		CAMPGROUND		CONTROL		CAMPGROUND	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Mourning Dove	----	----	----	----	----	----	----	----	----	----	9.9	9.9
Broad-tailed Hummingbird	19.8	19.8	24.7	----	----	19.8	9.9	9.9	19.8	19.8	9.9	9.9
Red-shafted Flicker	----	----	9.9	9.9	----	----	9.9	9.9	----	----	9.9	19.8
Hairy Woodpecker	----	----	9.9	----	19.8	----	9.9	----	----	19.8	----	9.9
Yellow-bellied Sapsucker	----	----	----	----	----	----	9.9	----	----	----	----	9.9
Cassin's Kingbird	----	----	----	----	----	----	----	----	----	19.8	----	----
Black Phoebe	19.8	19.8	----	----	----	----	----	----	----	----	----	----
Western Flycatcher	19.8	19.8	----	----	----	----	----	----	----	----	----	----
Western Wood Pewee	----	39.5	----	9.9	----	19.8	----	19.8	----	39.5	----	----
Steller's Jay	39.5	19.8	49.5	24.7	19.8	----	19.8	19.8	19.8	19.8	19.8	19.8
White-breasted Nuthatch	----	----	9.9	9.9	----	----	29.7	19.8	----	----	----	----
Pygmy Nuthatch	----	----	----	----	19.8	19.8	19.8	9.9	19.8	19.8	9.9	19.8
House Wren	59.3	59.3	39.6	39.6	19.8	39.5	39.6	29.7	59.3	59.3	19.8	39.6
Robin	39.5	39.5	44.5	29.7	19.8	19.8	29.7	19.8	----	39.5	29.7	39.6
Solitary Vireo	49.4	49.4	9.9	----	----	19.8	9.9	9.9	19.8	19.8	----	----
Warbling Vireo	----	----	----	----	----	----	9.9	----	----	19.8	----	----
Virginia's Warbler	----	----	----	----	----	----	----	----	----	39.5	----	----
Grace's Warbler	----	----	9.9	----	----	19.8	19.8	----	----	9.9	29.7	19.8
Painted Redstart	----	----	9.9	----	19.8	39.5	9.9	----	----	----	----	----
Red-faced Warbler	----	19.8	----	----	----	19.8	----	4.9	----	----	----	----
Bullock's Oriole	19.8	19.8	14.8	14.8	----	19.8	19.8	19.8	----	19.8	----	19.8
Western Tanager	----	----	----	----	----	----	----	----	----	----	9.9	9.9
Hepatic Tanager	----	19.8	----	----	----	----	----	----	----	----	----	----
Summer Tanager	----	----	----	----	19.8	19.8	9.9	9.9	----	19.8	----	----
Black-headed Grosbeak	59.3	39.5	64.3	39.6	19.8	39.5	39.6	39.6	39.5	19.8	29.7	39.6
Lesser Goldfinch	----	----	----	----	----	----	----	----	----	19.8	----	----
Rufous-headed Towhee	----	----	----	----	----	----	----	----	19.8	19.8	----	----
Total Density	326.0	365.6	297.0	178.2	158.4	296.7	297.0	222.7	178.1	445.0	178.2	257.4
Species Richness	9	12	12	8	8	12	16	13	7	17	10	12
Weight/Individual	40.0	31.7	52.7	54.2	46.8	23.4	39.4	41.6	27.7	32.3	53.3	52.3
SCB	26078.4	23178.5	31315.7	19316.9	14830.2	13858.6	23397.6	18509.0	9854.2	28710.0	19013.8	26918.0
EE	11697.7	11438.6	12302.4	7698.6	6088.0	7785.7	10166.4	8079.5	4984.0	13783.8	7134.0	10203.0

Table 2.--Species recorded on or immediately adjacent to the study area. [Note; Bird scientific names according to A.O.U. Checklist, 1957; and 32nd A.O.U. Supplement, Auk 90(2): 411-419.]

Red-tailed Hawk	Buteo jamaicensis
Turkey Vulture	Cathartes fasciata
Band-tailed Pigeon	Columba fasciata
Mourning Dove	Zenaidura macroura
Great Horned Owl	Bubo virginianus
Flammulated Owl	Otus flammeolus
White-throated Swift	Aeronautes saxatalis
Broad-tailed Hummingbird	Selasphorus playcercus
Belted Kingfisher	Megaceryle alcyon
Red-shafted Flicker	Colaptes cafer
Hairy Woodpecker	Dendrocopos villosus
Yellow-bellied Sapsucker	Sphyrapicus varius
Western Kingbird	Tyrannus verticalis
Cassin's Kingbird	Tyrannus vociferans
Black Phoebe	Sayornis nigricans
Western Flycatcher	Empidonax difficilis
Western Wood Pewee	Contopus sordidulus
Violet-green Swallow	Tachycineta thalassina
Steller's Jay	Cyanocitta stelleri
Common Raven	Corvus corax
Mountain Chickadee	Parus gambeli
Dipper	Cinclus mexicanus
White-breasted Nuthatch	Sitta carolinensis
Pygmy Nuthatch	Sitta pygmaea
Brown Creeper	Certhia familiaris
House Wren	Troglodytes aedon
Canyon Wren	Catherpes mexicanus
Mockingbird	Mimus polyglottos
Robin	Turdus migratorius
Hermit Thrush	Catharus guttata
Townsend's Solitaire	Myadestes townsendi
Ruby-crowned Kinglet	Regulus calendula
Solitary Vireo	Vireo solitarius
Warbling Vireo	Vireo gilvus
Virginia's Warbler	Vermivora virginiae
Yellow Warbler	Dendroica petechia
Audubon's Warbler	Dendroica auduboni
Grace's Warbler	Dendroica graciae
MacGillivray's Warbler	Oporonis tolmiei
American Redstart	Setophaga ruticilla
Painted Redstart	Setophaga picta
Red-faced Warbler	Cardellina rubrifrons
Wilson's Warbler	Wilsonia pusilla
Hooded Oriole	Icterus cucullatus
Bullock's Oriole	Icterus galbula
Brown-headed Cowbird	Moluthrus ater
Western Tanager	Piranga ludoviciana
Hepatic Tanager	Piranga flava
Summer Tanager	Piranga rubra
Rose-breasted Grosbeak	Pheucticus ludovicianus
Black-headed Grosbeak	Hesperiphona vespertina
Indigo Bunting	Passerina cyanea
Pine Siskin	Spinus pinus
American Goldfinch	Spinus tristis
Lesser Goldfinch	Spinus psaltria
Rufous-sided Towhee	Pipilo erythrophthalmus
Gray-headed Junco	Junco caniceps

were seen on or immediately adjacent to the study areas. Of these, 23 species nested on one or both of the study areas at least once during the three years of censusing. The density and species' richness (Whittaker 1970) are summarized in Table 3. The changes in these values and other resultant calculations prior to and after the opening of the campground are discussed below as indicators of human impact upon the breeding bird community.

Avian Density and Species Richness

Every species is apparently adjusted to breed at the time of year at which it can raise its young most efficiently (Immelmann 1971). For most northern temperate birds this nesting period extends from late spring to mid-summer (Lack 1950). This is certainly true for the Cave Springs area of Oak Creek Canyon, where breeding begins about mid-April and lasts through July. The campground opening date falls within this period.

1973.--In 1973 a total of 17 species nested on one or both of the study areas (Table 3). A 40 percent decrease in density occurred on the campground after the opening day. Part of the losses incurred were through direct human manipulation of the nest site. Forest Service employees, by removing trees and slash, destroyed 20 percent of the Steller's Jay nests. Campers destroyed 30 percent more of the Steller's Jay nests and 20 percent of the Robin nests by removing branches for firewood, making room for tents, and other reasons.

The parulid warblers, Solitary Vireos, Broad-tailed Hummingbirds, and Hairy Woodpeckers abandoned their nests but occasionally foraged within the area. No losses can be attributed to adults leaving with fledged young prior to the opening date. Of those actually nesting on 20 May 1973, breeding had not proceeded beyond the incubation stage.

The density on the control site increased 12.1 percent after the opening date. This was not due to individuals emigrating from the campground but rather to the arrival of mid-summer breeders, namely, the Red-faced Warbler, Western Wood Pewee, and Hepatic Tanager (Bent 1968).

After the opening of the campground, species richness went from 12 to 8 on the campground and increased from 9 to 12 on control.

1974.--In 1974 a total of 17 species nested on one or both of the study areas (Table 3). However, these were not the same 17 of 1973. There was a change of three species, with Black Phoebes, Western Flycatchers and Hepatic Tanagers being replaced by Pygmy Nuthatches, Warbling Vireos and Summer Tanagers. This area in Oak Creek is an ecotonal situation between confierous forest and a deciduous

riparian habitat. The Summer Tanager prefers cottonwoods along streams for nest sites and apparently found conditions suitable in 1974. On the other hand, the Hepatic Tanager prefers pines and oaks and found Cave Springs acceptable in 1973. It is probably subtle environmental differences (i.e., temperature, rainfall, etc.) that determine which tanager will be present in what might be considered marginal habitat for either.

A 25 percent decrease in densities occurred on the campground, whereas there was a dramatic 87.3 percent increase on control. The campground was opened 12 days earlier than in 1973 and may account for the initially low density on control. It was simply too early for many species to be breeding. Yet initial densities on the campground matched 1973 figures. No satisfactory explanation has been found.

Species richness dropped from 16 to 13 on the campground and climbed from 8 to 12 on control.

1975.--During 1975 a total of 21 species nested on one or both of the study areas (Table 3). New breeders included Mourning Doves, Cassin's Kingbirds, Virginia's Warblers, Western Tanagers, Lesser Goldfinches, and Rufous-sided Towhees. In previous years all of these had either appeared as transients or nested within the canyon but off the study areas.

In 1975 for the first time there was in increase in density (44.4 percent) on campground. In 1973 and 1974 breeding activity was well underway on the campground prior to the opening date. In 1975, however, colder temperatures, higher winds, and increased precipitation postponed breeding. In many species a positive correlation between temperature and the rate of testicular development or egg production has been found (Farner and Wilson 1957). In 1975 the average temperature two weeks prior to opening was 57.7°F and for the same period in 1973 and 1974 was 63.7°F and 62.5°F, respectively. Perusal of the 1975 censuses indicates almost no breeding activity (i.e., singing, displaying, nest building) before 16 May.

It is interesting to note that once breeding did commence, the maximum density reached was still less than the maximum measured in 1973 and 1974.

On control there was in increase of 149.8 percent. This phenomenal climb is also no doubt related to the later breeding period. Before the opening day, weather conditions were too severe for breeding to commence. In addition, several species that would normally nest elsewhere (e.g., Rufous-sided Towhees usually nest in the chaparrel found on the canyon walls and Lesser Goldfinches usually nest above the rim) were found on the control. Perhaps environmental conditions were relatively less severe within the canyon than elsewhere and these species chose to accept marginal habitat under these limitations.

Species richness went from 10 to 12 on the campground and 7 to 17 on control.

Yearly fluctuations of density on each area are difficult to explain because of so many determining factors. Not only local weather but events on the wintering grounds can play an important role in predicting a particular year's breeding population. Attempts to explain avian population fluctuations have so far led to only ambiguous conclusions (Von Haartman 1971). It is pertinent to note, though, that over the three-year period there was nearly twice the range of densities on control as the campground.

Avian Diversity and Habitat Diversity

MacArthur (1964) found a correlation between BSD and FHD in "tall forests of sycamores and cottonwoods" in southeastern Arizona. The relationship in this study between BSD and FHD was almost identical to what he and others found in earlier studies in eastern deciduous forests (MacArthur and MacArthur 1961, MacArthur et al. 1962). Austin (1970), working in "desert riparian" habitats in Nevada, plotted his data against MacArthur's (1964) regression line for BSD vs. FHD and found similar results. Carothers et al. (1974) found that in "desert riparian" habitats immediately adjacent to areas of relatively higher productivity but low avian densities, the BSD and FHD correlation no longer held. Yet, Carothers found that in "desert riparian" habitats immediately adjacent to areas of relatively the same productivity and having a compliment avian community, the BSD and FHD relationships did come close to MacArthur's regression line.

The BSD's and FHD's obtained in Oak Creek are summarized in Table 4 and graphed in Figure 1. Although the points do cluster around MacArthur's line, there is enough deviation to suggest other forces at work besides foliage height diversity.

As in Carother's study plots, this is a riparian system and MacArthur's line fails to take into account the added dimension of permanent water. Also, human disturbance is not considered. An additional downfall of FHD is that there has been no stipulation by past investigators when to measure FHD. As we see here, BSD and FHD vary through time (or sampling error). BSD was measured from the first signs of breeding to the opening date and then from that date to the end of breeding activity. On the other hand, FHD was measured once before and once after. It is possible that a day could be found during the vegetative growing season when the FHD would be such that BSD for the entire period matched MacArthur's line. This leads me to question the value of FHD as a predictor of BSD except in those specific cases studied by MacArthur and the need for

Table 4.--Bird species diversity and habitat diversity.

	CAMPGROUND				CONTROL			
	Bird Species Diversity (BSD)		Foliage Height Diversity (FHD)		Bird Species Diversity (BSD)		Foliage Height Diversity (FHD)	
	Before	After	Before	After	Before	After	Before	After
1973	2.19	1.95	.98	1.00	2.08	2.34	1.04	1.08
1974	2.62	2.42	.96	.98	2.08	2.43	1.06	1.05
1975	2.19	2.34	.97	1.01	1.83	2.71	.99	.97

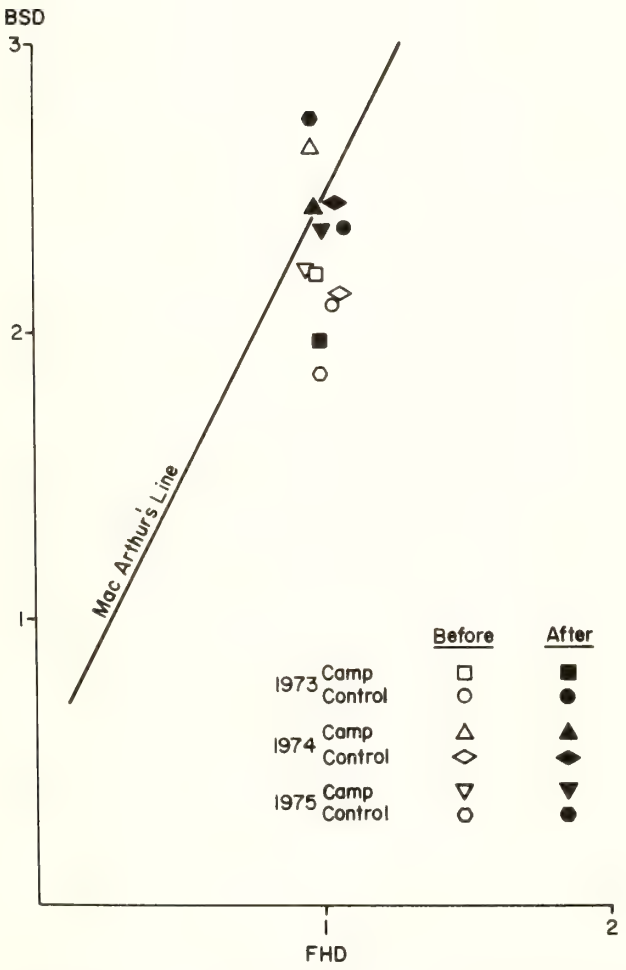


Figure 1.--Bird species diversity (SD) as a function of foliage height diversity (FHD) before and after occupation of the campground by campers. Regression line from MacArthur et al. 1966.

Table 5.--Individual bird weights[1] and individual existence energy.

Species	Weight in Grams	Existence Energy
Mourning Dove	137.5	31.79
Broad-tailed Hummingbird	4.0	2.94
Red-shafted Flicker	125.3	29.90
Hairy Woodpecker	69.8	20.15
Yellow-bellied Sapsucker	45.0	15.00
Cassin's Kingbird	45.4	21.47
Black Phoebe	18.6	12.71
Western Flycatcher	12.5	10.06
Western Wood Pewee	14.0	10.75
Steller's Jay	105.0	35.14
White-breasted Nuthatch	20.4	13.42
Pygmy Nuthatch	10.0	8.82
House Wren	10.5	9.08
Robin	88.0	31.67
Solitary Vireo	13.5	10.53
Warbling Vireo	11.3	9.48
Virginia's Warbler	8.4	7.97
Grace's Warbler	7.5	7.45
Painted Redstart	9.7	8.67
Red-faced Warbler	9.7	8.67
Bullock's Oriole	35.7	18.64
Western Tanager	28.0	16.16
Hepatic Tanager	40.0	19.93
Summer Tanager	35.5	18.58
Black-headed Grosbeak	46.0	21.63
Lesser Goldfinch	8.7	8.13
Rufous-sided Towhee	38.9	19.60

1 From Carothers et al. 1973, Marshall 1972, and collections of the Museum of Northern Arizona

specific time limitations when these parameters are to be measured.

Examining BSD, we see that in 1973 and 1974 there was a decrease in diversity on the campground after it was opened. An increase occurred on control. In 1975, contol's diversity again increased but so did the campground's. The reason for this is, once again, the late breeding season in 1975 (see previous section).

Bioenergetics

In order to better understand the energetics and organization of these avian communities, it is important to look at standing crop biomess (SCB) and existence energy (EE) of the birds (Salt 1957, Karr 1968). The former is the total weight (in grams) of the entire avian community. In order to consider community metabolism, a conversion is made that reflects the difference in metabolism due to differences in body weight. This is expressed as existence energy (or Kcal) consumed by the total avian community (see Carothers et al. 1974 for limitations of this measure).

1973.--The SCB of control decreased slightly after 29 May, although density increased. This is possible because the average weight per individual bird decreased from 40.0 g to 31.7 g. Table 3 shows that several small-bodied birds, Western Wood Pewees and Red-faced Warblers, did move onto the area; see Table 5 for weights. Two larger species, Steller's Jays and Black-headed Grosbeaks, moved off the area.

The campground had a drastic SCB decrease; however, the average weight per individual remained essentially constant (52.7 g to 54.2 g). The decrease can therefore only be attributed to a general loss of birds of all sizes.

The initial and final differences between the average weight per individual values on the control and campground show that relative to each other light-weight birds inhabited the control and heavier birds inhabited the campground.

The existence energy values were initially the same but after the opening the campground EE showed a decrease of 37.3 percent.

We see then that before the intrusion of campers the two areas differed in the average weight per individual by 12.7 g but the EE was the same. Following campground occupation, the average weight per bird became more dissimilar (22.5 g), and the total community EE was nearly halved on the campground.

1974.--The SCB of control, once again, decreased slightly after the opening, although density increased. Again, this was due to a decrease in the average weight per individual bird (46.8 g to 23.4 g) caused by an influx of smaller-bodied species (Table 3 and 4).

The campground SCB decreased greatly, as in 1973, and the average weight per individual remained fairly constant.

In 1974, larger-bodied birds occupied the control initially, but this changed sharply after the opening of the campground.

EE values on control changed upwardly 27.8 percent, whereas the campground's was decreased by 22.3 percent.

Once again, the opening appears to be detrimental to the birds in the campground.

1975.--The overall trends remained the same in 1975. Smaller-bodied birds made up a majority of the population on control. The increase in SCB and EE on the campground, of course, was related to the density increase that year.

SUMMARY AND MANAGEMENT ALTERNATIVES

After three breeding seasons, several phenomena were discerned: 1) although bird densities on the campground and control are similar before the campground opening date, the average weights of an individual bird is greater on the campground ($\bar{x}$ = 48.5 g) than on control ($\bar{x}$ = 38.2 g) and 2), population density and species diversity (H') decrease when the campground is occupied by people.

In other words, the presence of the campground produced a significant shift in the avian community to heavier bodied birds relative to the natural control area. This is probably a response to the "opening" of the habitat during campground construction. Inhabitation of the campground by people causes a direct reduction in the numbers and kinds of breeding birds.

Those in managerial posistions might consider the following suggestions:

1. Locations for new campgrounds should be carefully scrutinized in terms of usage by wildlife. In this specific case, riparian habitats are very important to birds and of such a limited extent in the Southwest that further destruction of habitat needs to be discouraged.

2. Existing campgrounds should be periodically closed to allow regeneration of vegetation and reduce stress on resident wildlife. This is being done in Oak Creek Canyon, but much too often the reason behind the closure is financial rather than ecological.

3. Opening the campground before or after the height of the breeding season may be better for the avifauna. If people are already present when birds arrive to nest, the birds may be able to find suitable habitat elsewhere instead of "wasting energy" by attempting to breed and then being disrupted during incubation. Of course, not opening the campground until after breeding season would be ideal for the birds but probably very impractical for the campers.

4. Habitat manipulation should be carefully controlled. This includes breaking off branches

for firewood, trenching for tents, running of noisy equipment, and even clearing of snags, slash, and brush by USFS crews.

5. Educational programs may be the only effectual solution of human recreation and wildlife problems. Government agencies have had very good results in some public educational canpaigns (e.g., Smokey the Bear). There is no reason the general public could not be exposed to broad ecological concepts such as camping with less impact.

Finally, it is hoped that studies of this type and education of the public will lead to a happy medium between preserving native wildlife and also allowing human enjoyment of an area.

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Population Fluctuations in Nocturnal Rodents in the Lower Colorado River Valley[1]

Bertin W. Anderson, Jeff Drake, and Robert D. Ohmart[2/]

Abstract.--An examination of population fluctuations in a sample of over 10,000 rodents comprising five species collected along the lower Colorado River revealed distinct seasonal (annual) cycles in Perognathus penicillatus and Dipodomys merriami. Overall rodent populations were decreasing for the 3.5 year period for which data are presented. This was most pronounced in Peromyscus eremicus. Although these populations were declining, there was significant intraspecific asynchrony among the populations in different vegetation types. There was also a significant degree of interspecific asynchrony in population fluctuations which renders the task of evaluating habitat difficult and subject to error unless carried out for several years in various vegetation types.

INTRODUCTION

Populations are said to be cyclic when they alternately irrupt and subside in a more or less uniform manner between high and low levels of density. These population fluctuations sometimes follow a general pattern with respect to time (annual, seasonal, monthly). Cyclic events broken into finer detail follow four fundamental phases: increase, peak, decline, and low density. Several studies have investigated cyclic events exhibited by microtine rodents, which experience cycles of three-to-four and nine-to-ten year intervals as well as annual fluctuations (Dymond 1947, Elton 1942, Keith 1963, Pearson 1966, Speirs 1939, Wing 1961), while McClosky (1972) has studied temporal changes in densities and diversities over short periods of time.

Designating fluctuations as cyclic implies considerable regularity. However, the cause of cyclic populations can usually be expected to contain random components inextricably mixed with any systematic ones. If the random components outweigh the systematic ones or if different substrates respond differently to the systematic components, the occurrence of noncyclic or asynchronous populations becomes predominant.

The causal mechanism of cycles include biotic as well as abiotic factors. Biotic factors affecting animal cycles are those inherent in the populations themselves and in the interrelations of different species. These include disease, predation, food, and physiological mechanisms. Abiotic factors are the physico-chemical element of the environment such as organic compounds, moisture, winds, solar radiation and others.

The purpose of this report is to examine the annual population cycles of nocturnal rodents in the lower Colorado River Valley. Coupled with this examination are observations dealing with general population trends over the course of the study, as well as an evaluation of fluctuations occurring in various community types. The study was initiated in September 1973 and is on-going; data will be presented through March 1977.

1/ Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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CLIMATE AND VEGETATION

Climate

The study area includes a major part of the riparian vegetation located along the Colorado River from the Mexican boundary north to the Nevada border at Davis Dam. Climatic data were supplied by the U.S. Bureau of Reclamation and the Palo Verde Irrigation District. Rainfall is highly irregular, with annual amounts rarely exceeding 26 cm (Table 1). Drought conditions prevail throughout most of the year. Over the 3.5 years of this study, the highest monthly rainfall was recorded in September 1976 (6.45 cm). The highest annual rainfall (12.97 cm) was also recorded in 1976. Although the area receives little rain, the water table is high and established vegetation with roots at least 3 m deep rarely shows ill effects. Annuals, a staple food source for rodents, are very dependent upon rainfall.

Temperatures in the desert are highly variable and show a wide range between daily and annual extremes (Table 2). The highest official temperature was 50.0°C in July 1973; the lowest was -5°C in January 1973, although we recorded a temperature of -14°C near

Table 1.--Rainfall on the lower Colorado River.

	Precipitation (cm)						
Month	1972	1973	1974	1975	1976	1977	Twenty-year average
Jan.	0.00	0.12	1.60	0.13	0.00	0.48	0.76
Feb.	0.00	3.07	0.00	0.08	3.66	0.02	0.81
Mar.	0.00	1.85	0.94	0.69	0.05	0.13	0.71
Apr.	0.00	0.00	1.50	1.75	0.00	0.00	0.33
May	0.00	0.12	0.00	0.00	0.00		0.03
June	1.75	0.00	0.00	0.00	0.00		0.08
July	0.00	0.00	2.06	0.00	0.00		0.51
Aug.	2.18	5.84	1.78	0.00	0.00		1.68
Sept.	0.00	0.00	0.00	2.44	6.45		0.84
Oct.	6.63	0.00	0.61	0.05	0.25		1.17
Nov.	1.55	0.28	0.00	0.00	0.38		0.66
Dec.	0.10	0.00	1.24	0.00	0.43		1.17
Total	12.2	11.3	8.23	4.89	12.97		8.75

Table 2.--Temperatures for the lower Colorado River.

	Mean High and Low Temperatures (°C)											
Month	1973		1974		1975		1976		1977		Twenty-year average	
Jan.	18.0	3.0	18.2	4.8	20.8	2.3	21.4	3.0	19.8	3.6	20.1	3.7
Feb.	20.9	7.6	22.3	5.1	21.6	3.9	21.8	3.3	25.4	4.7	22.8	6.5
Mar.	21.7	8.4	26.4	9.9	23.7	7.8	24.5	8.5	23.6	6.2	25.9	9.0
Apr.	29.1	11.4	30.0	12.2	25.1	9.7	27.5	11.2	31.9	11.3	29.8	12.3
May	37.2	17.5	35.1	17.8	33.8	14.9	35.4	18.0			34.8	16.9
June	41.3	22.9	43.2	23.3	39.6	20.6	40.2	20.9			39.8	21.5
July	42.7	25.6	41.2	26.2	42.2	26.3	40.5	25.7			42.3	26.0
Aug.	41.2	24.3	41.5	23.9	42.2	24.6	40.6	23.0			41.4	25.5
Sept.	38.3	19.3	38.8	23.3	38.3	22.8	34.6	21.4			38.4	25.5
Oct.	32.8	13.2	32.1	15.8	31.1	14.0	31.0	14.7			31.8	14.6
Nov.	23.9	7.8	24.7	8.5	25.8	8.7	26.2	8.0			24.5	8.1
Dec.	21.3	4.2	18.2	3.3	20.9	5.1	19.7	2.6			19.9	4.0

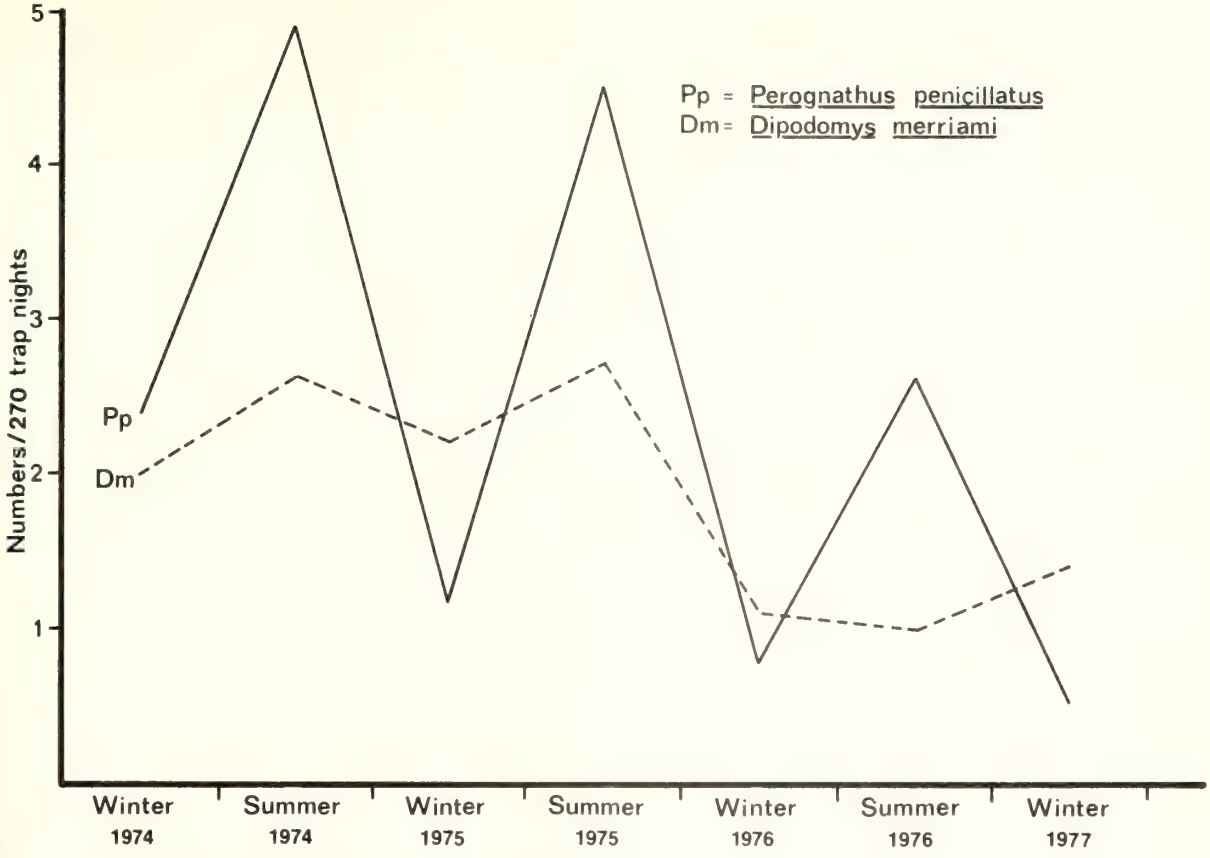


Figure 1.--Densities (N/270tn) of Perognathus penicillatus and Dipodomys merriami along the lower Colorado River Valley.

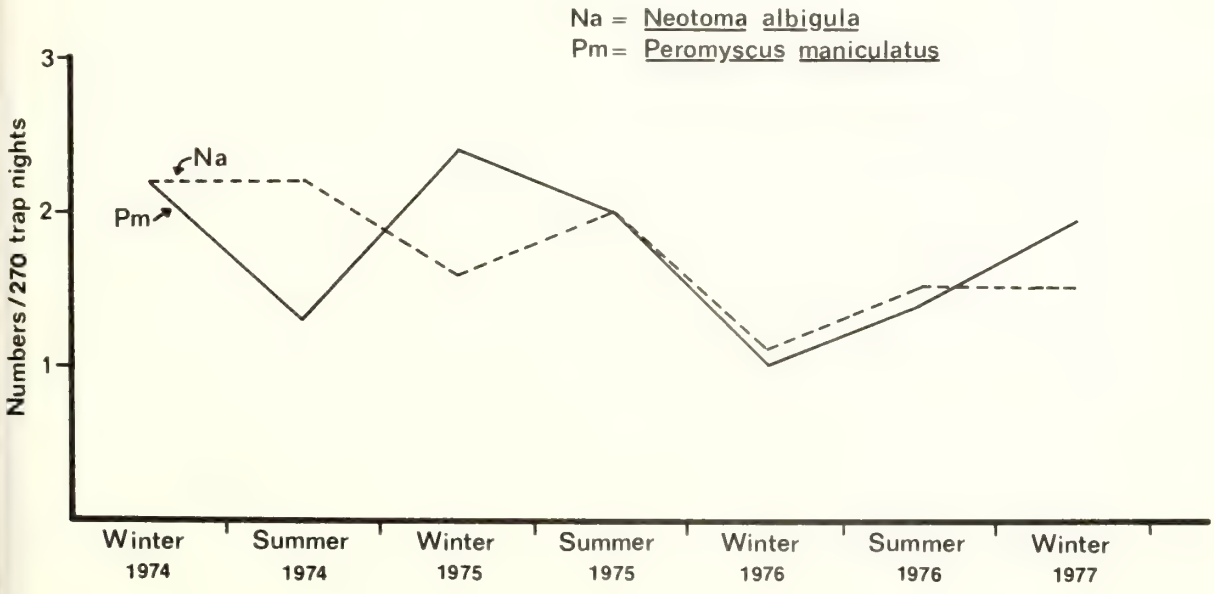


Figure 2.--Densities (N/270tn) of Peromyscus maniculatus and Neotoma albigula along the lower Colorado River Valley.

Needles, California in January 1975.

Vegetation

In this study we recognized six basic community types in the riparian vegetation. Data from four of these (cottonwood-willow, Populus fremontii-Salix gooddingii; salt cedar, Tamarix chinensis; honey mesquite, Prosopis juliflora; and screwbean mesquite, P. pubescens) are presented in this report. The criteria used in defining these communities are included elsewhere in these proceedings (Anderson, Engel-Wilson, Wells, and Ohmart) and will not be repeated here.

METHODS AND MATERIALS

Within the study area approximately 100 transects (the actual number varied from year to year) were established throughout the various community types. Rodent populations were sampled in transected areas with a snap trap grid consisting of two parallel lines 15 m apart. Each line included 15 stations that were each 15 m apart. At each station two museum special traps and one Victor rat trap were set and baited with rolled oats and peanut butter treated with a chemical to repel insects (Anderson and Ohmart, 1977). Trap lines were run for three consecutive nights. Catches are expressed as numbers per 270 trap nights. (For further details see Anderson, Engel-Wilson, Wells and Ohmart, these proceedings.)

All community types were sampled on an approximately equal basis throughout the study. Trap nights for the 3.5 year period totaled 150,930. The number of grids per season ranged from 44 (11 per community type) to 116 (29 per community type). For this study we recognized two seasons: summer, April through October, and winter, November through March.

The species which were most frequently caught and which were analyzed for this report were the cactus mouse (Peromyscus eremicus), deer mouse (P. maniculatus), desert pocket mouse (Perognathus penicillatus), white-throated woodrat (Neotoma albigula), and Merriam's kangaroo rat (Dipodomys merriami). During the study we caught 6,178 Peromyscus eremicus, 829 P. maniculatus, 881 Neotoma albigula, 1,736 Perognathus penicillatus, and 1,317 D. merriami. Other species such as the grasshopper mouse (Onychomys torridus), desert kangaroo rat (Dipodomys deserti) and several others were caught regularly but numbers were too small for analysis.

ANNUAL CYCLES AND POPULATION TRENDS

The presence of annual population cycles for the five numerically dominant rodent species was investigated by capture data, within each season, and from the four sampled community types. In the combined analysis we are considering seasonal population fluctuations within the total riparian habitat. The presence of an annual cycle should be evident if there are regular and predictable population fluctuations between seasons. Analysis of annual cycles should reveal general population trends, but obscure intercommunity trends. Therefore, overall trends are analyzed at the community level as well as the species level.

Perognathus penicillatus and Dipodomys merriami exhibited regular annual cycles (fig. 1). Peak population levels were reached in summer and low levels in the winter. The pattern was more developed in P. penicillatus than in D. merriami or Neotoma albigula. N. albigula maintained a nearly constant population level from winter 1974 to summer 1974 at which time the population began to fluctuate in a manner similar to that shown by P. penicillatus and D. merriami. The seasonal fluctuations shown by N. albigula and Peromyscus maniculatus (fig. 2) are not readily interpreted. P. maniculatus showed high populations in winter and low populations for summer 1974 through summer 1975, but in winter 1976 the population declined precipitously.

Peromyscus eremicus demonstrated a complete lack of any annual cycle (fig. 3). The pattern was almost a linear progression of declining population for nearly the entire study period with only a slight increase in winter 1977. This overall population decline was found with some degree of consistency in each species examined. In all cases 1976 winter populations were lower than 1974 winter populations, but most 1977 winter populations showed a slight increase. In Perognathus penicillatus and Neotoma albigula the summer populations also showed a gradual decline. Summer populations of Peromyscus maniculatus increased substantially from 1974 to 1975 whereas summer populations of Dipodomys merriami increased only slightly.

The general decline in rodent numbers appears to be related to precipitation. With the exception of September 1975, dry conditions prevailed from September 1973 through January 1976 (Table 1), but in 1972 and in spring 1973 wet conditions existed long enough for seed-producing annuals to flower abundantly (pers. obs., R. D. Ohmart). Seed production continued for a while after a return to dry conditions and species that cache seeds can probably survive on these stores for some time. There



Figure 3.--Seasonal densities (N/270tn) of Peromyscus eremicus along the lower Colorado River Valley.

s a lag in the effect of changing conditions n the population densities. One might have xpected populations to have peaked in 1974, ollowing the second breeding season after he favorable wet conditions of 1973. This s seen to be the case in three of the five pecies (figs. 1-3). Subsequent dry conditions esulted in almost no flowering of annuals in 974 and 1975. One might have expected popu- ations to be lower in 1975 and 1976, following he second breeding season after the onset of oor conditions. There was some flowering in pring 1976 and rather profuse flowering in winter and spring 1977. These favorable conditions would be expected to lead to an increase in rodent populations beginning with the onset of reproduction. However, another factor must be considered. The precipitation in September 1976 probably was responsible for an initial decrease in rodent populations, because the relatively heavy rains caused extensive flooding in much of the prime rodent habitat in honey mesquite. Standing water, a few cm to a meter deep, remained in many places from a few days to two weeks or more and many additional days were required for the mud to dry.

During the rains there was running water which, in many areas, carried away most of the screwbean and honey mesquite pod crop. Trapping in these areas yielded few rodents through May 1977.

Low temperatures may also have negative effects on rodent populations. The spring of 1975 was unusually cool with locally occurring freezing temperatures in March, April, and early May. These frosts may have been responsible for an almost total lack of mesquite pod production the following fall.

In summary, decreasing rodent populations from 1974 through early 1977 were probably the result of (1) dry conditions in which annual plants were unable to reproduce, (2) freezing spring temperatures in 1975 which may have affected mesquite seed productivity and (3) flooding of prime habitat in September and October 1976.

RODENT POPULATION TRENDS IN DIFFERENT PLANT COMMUNITIES

One of our purposes was to study the extent of synchrony in fluctuations between species both within and between community types. To do this we studied population trends of the five most abundant rodents in each community separately. Considerable asynchrony in population fluctuations between species at a locality would introduce additional difficulties in evaluating the rodent diversities and densities of different habitat types. If these interspecific fluctuations in population size also were asynchronous between localities, evaluation of habitats would be further complicated. In this section we explore these points and offer suggestions for the collection of useful data.

Intraspecific Fluctuations between Community Types

Fluctuations in populations of Perognathus penicillatus in the four community types studied were highly synchronous (fig. 4). Dipodomys merriami populations were synchronous in screwbean (SM) and honey mesquite (HM) and in salt cedar (SC) and cottonwood-willow (CW), but these two sets were asynchronous with respect to each other (fig. 5). Peromyscus maniculatus showed moderately asynchronous fluctuations (fig. 6); populations were increasing in cottonwood-willow at a time when they remained about the same or increased slightly in other community types. Neotoma albigula population fluctuations tended to be quite asynchronous (fig. 7). Peak populations were reached at a different time in all community types.

Peromyscus eremicus populations also showed a marked degree of asynchrony (fig. 8). We also noted some evidence of reproduction in October and November of 1976 (juveniles, scrotal males, females with enlarged mammae) in screwbean mesquite. This may be the first indication that the overall population will be increasing again.

Interspecific Fluctuations between Community Types

Interspecific variations in population were not of the same magnitude for all species, i.e. peaks may not be as high nor valleys as low in some species as in others. In addition highs and lows do not occur at the same time in all species. Finally, there were intercommunity differences. McClosky (1972) has shown that there were significant changes in densities and diversities in a relatively brief period of time within a locality. Our data tend to support his findings, but since we did not trap continuously in the same area over a long period of time, our data are not well-suited for analysis on a local level.

Because changes in densities of different species occur at different rates from season to season, species diversities also change from season to season (fig. 9). From summer 1974 to summer 1975 the diversity in cottonwood-willow nearly doubled, due primarily to a reduction in numbers of Peromyscus eremicus. In general, the greatest diversities were reached in the warm months when Perognathus penicillatus was present in the greatest numbers. Ranked from greatest to least diversity the communities would be ordered SM-HM-SC-CW, SM-CW-SC-HM, and SM-HM-SC-CW in the three summers, respectively. In the four winters the order would be SM-HM-SC-CW, HM-SM-SC-CW, SM-HM-CW-SC, and SM-SC-CW-HM, respectively. Had trapping only been conducted in 1974, the results would have indicated that rodent densities were greater and diversities lower than they are on the average, whereas 1976 trap results would have indicated lower populations and greater diversities than the average of all years. Obviously, for an accurate assessment of rodent population densities and diversities one should trap extensively in several community types over several years. There are, however, a number of important conclusions that could have been drawn had a concerted trapping effort been made for a relatively short time, e.g., three months in the summer and three months in the winter.

First, trapping at almost any time would reveal Peromyscus eremicus as the most abundant species and Perognathus penicillatus as having greater densities in the summer. Second,

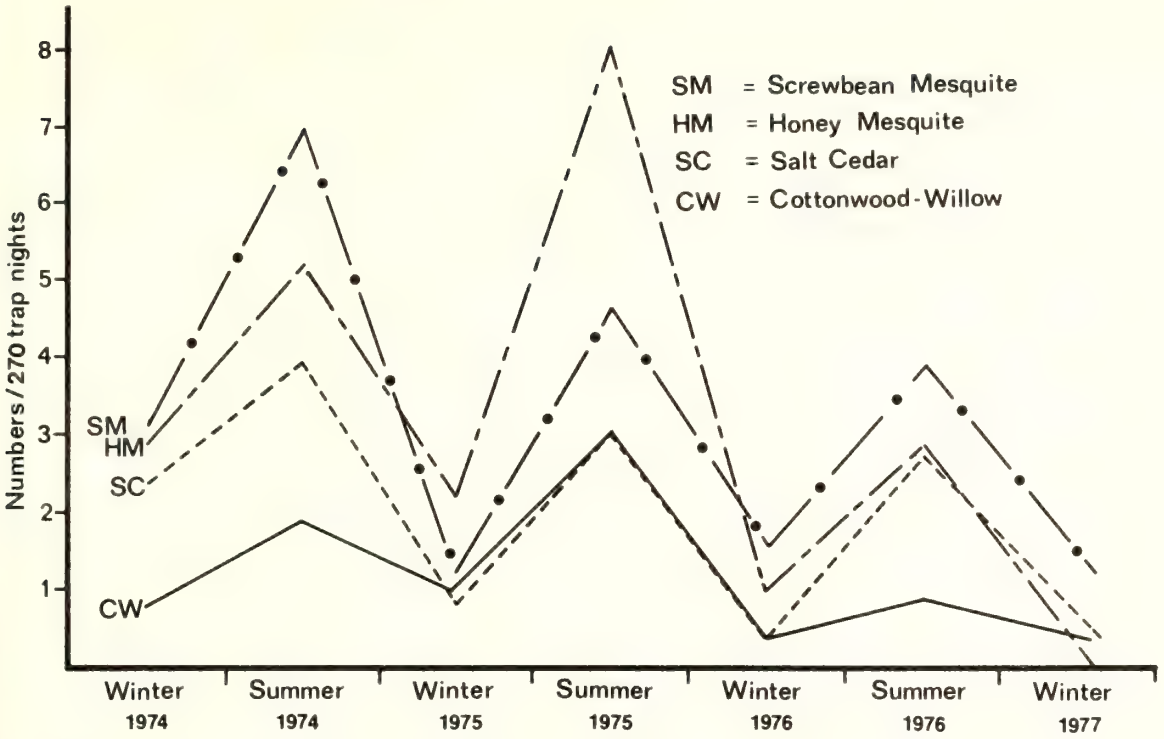


Figure 4.--Densities (N/270tn) of Perognathus penicillatus in four community types in the lower Colorado River Valley.

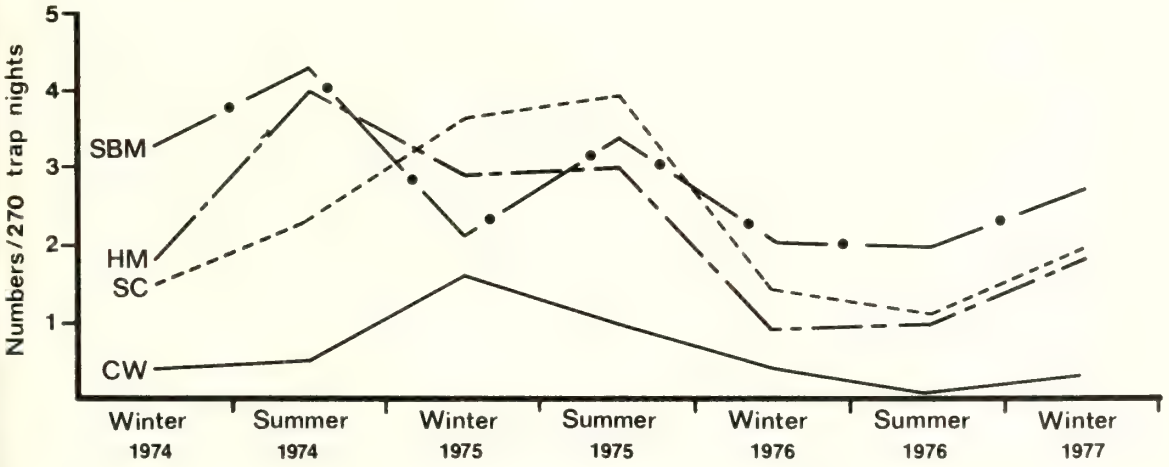


Figure 5.--Densities (N/270tn) of Dipodomys merriami in four community types in the lower Colorado River Valley.

liversities would be greatest in the summer. Caution should be exercised in determining he relative value of the various community ypes to rodents in terms of densities and iversities. Similarly, caution should be sed in identifying community preferences of ach species, but even with limited trapping

Perognathus penicillatus and Neotoma albigula should be most numerous in screwbean mesquite, Dipodomys merriami and P. penicillatus should be scarcest in cottonwood-willow and Peromyscus maniculatus and P. eremicus should be scarcest in honey mesquite.

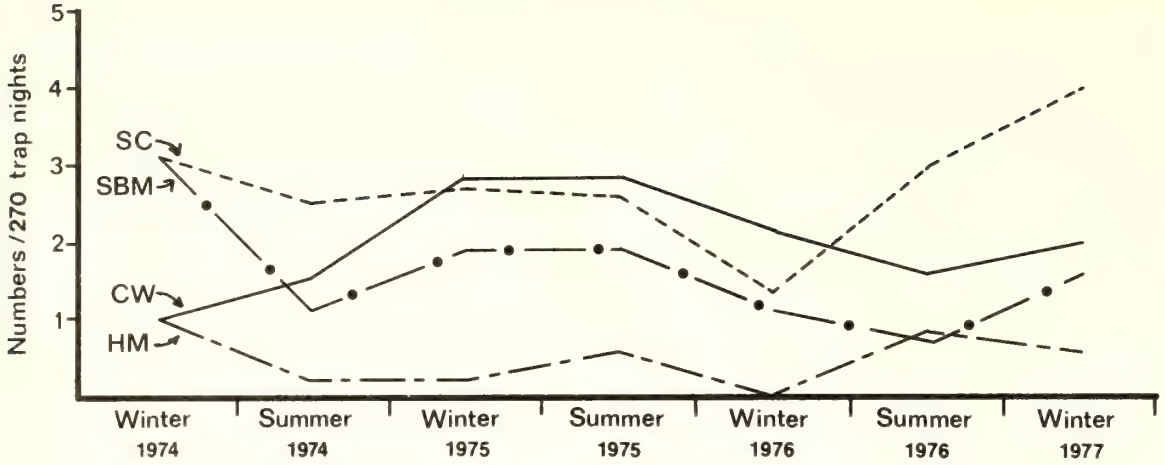


Figure 6.--Densities (N/270tn) of Peromyscus maniculatus in four community types in the lower Colorado River Valley.

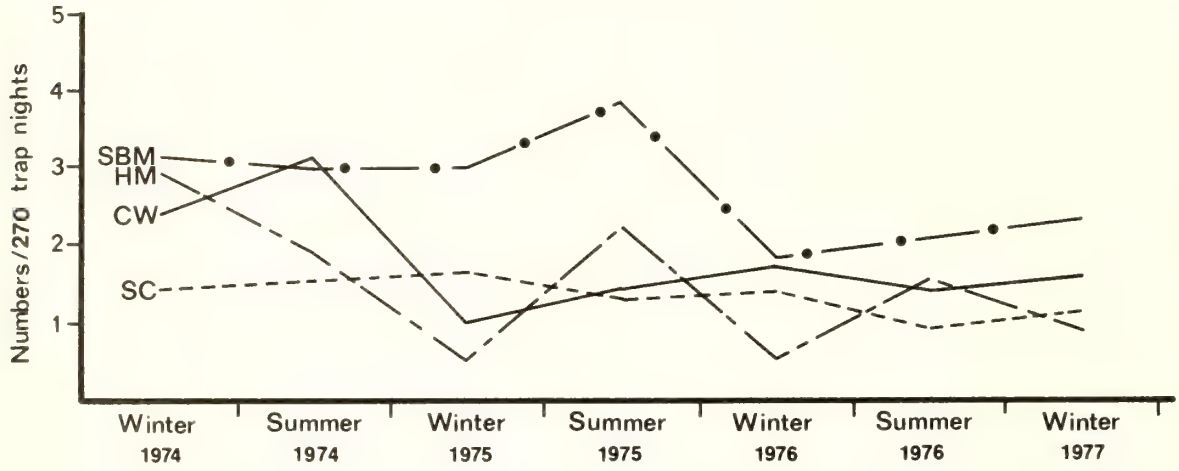


Figure 7.--Densities (N/270tn) of Neotoma albigula in four community types in the lower Colorado River Valley.

CONCLUSIONS

Perognathus penicillatus and Dipodomys merriami displayed distinct annual cycles which were synchronous with respect to each other and between the various community types. Longer term fluctuations displayed a high degree of asynchrony between community types within a given species as well as between species. The major factors which seem to have caused a steady decline in populations since 1974 are lack of rainfall up to September 1976, flooding in September 1976, and unusually cold temperatures in the spring of 1974. Because abiotic factors such as these occur in a more or less random pattern it seems possible that rodent populations in the lower Colorado River Valley do not display regular cycles although we have not trapped over a long enough period of time to draw a definite conclusion on this. The marked asynchrony in population fluctuations between community types within a given species and between species makes evaluation of habitat in terms of densities and diversities very difficult unless trapping is done over a period of two or three years in several community types.

ACKNOWLEDGMENTS

We wish to thank the many field biologists who have helped in collecting data. We are grateful to Jack Gildar for computerizing the data. The efforts of the secretarial staff in typing early drafts and of Penny Dunlop and Katherine Hildebrandt in typing the final manuscript are greatly appreciated. Linda Cheney kindly prepared the illustrations.

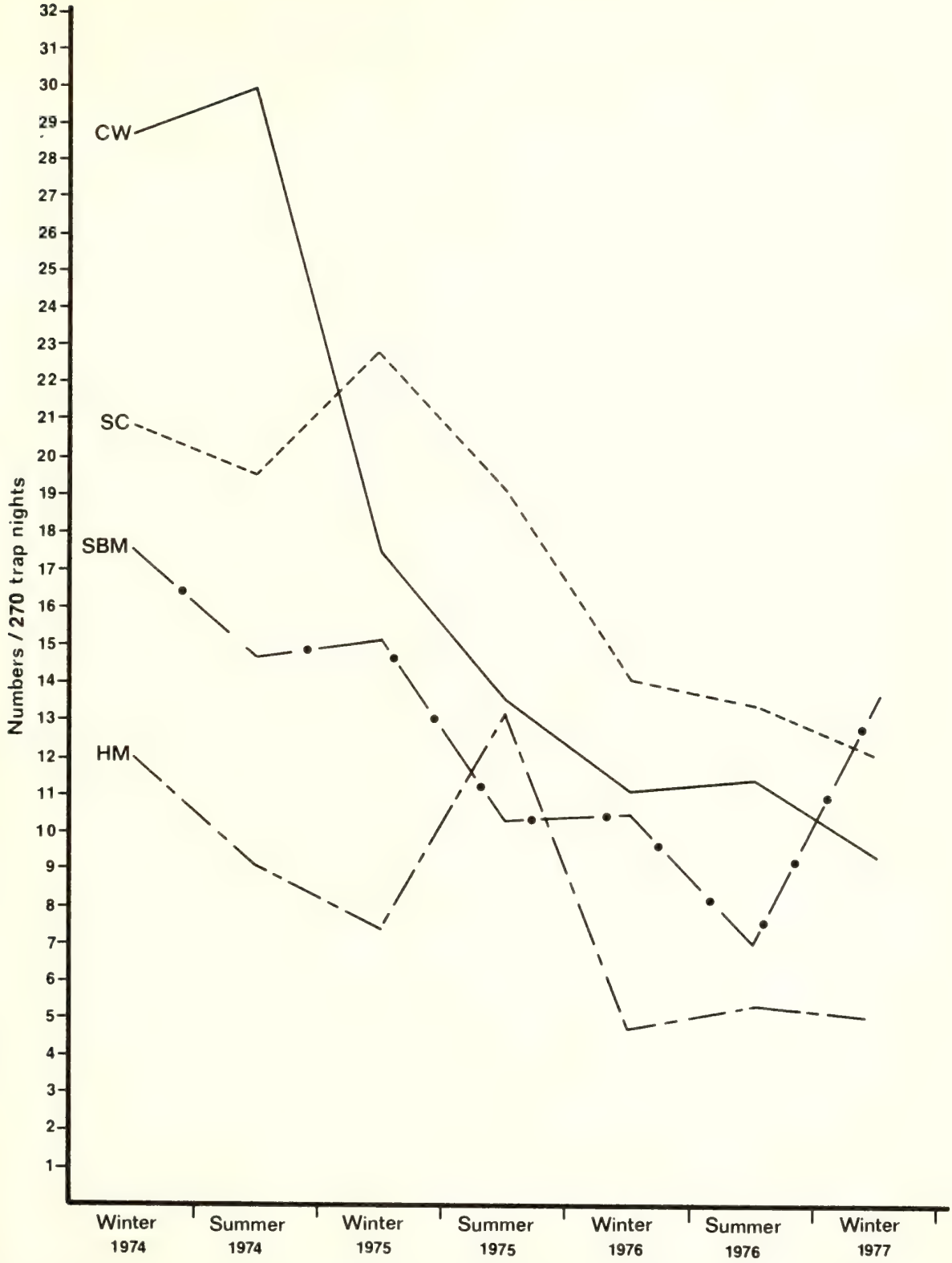
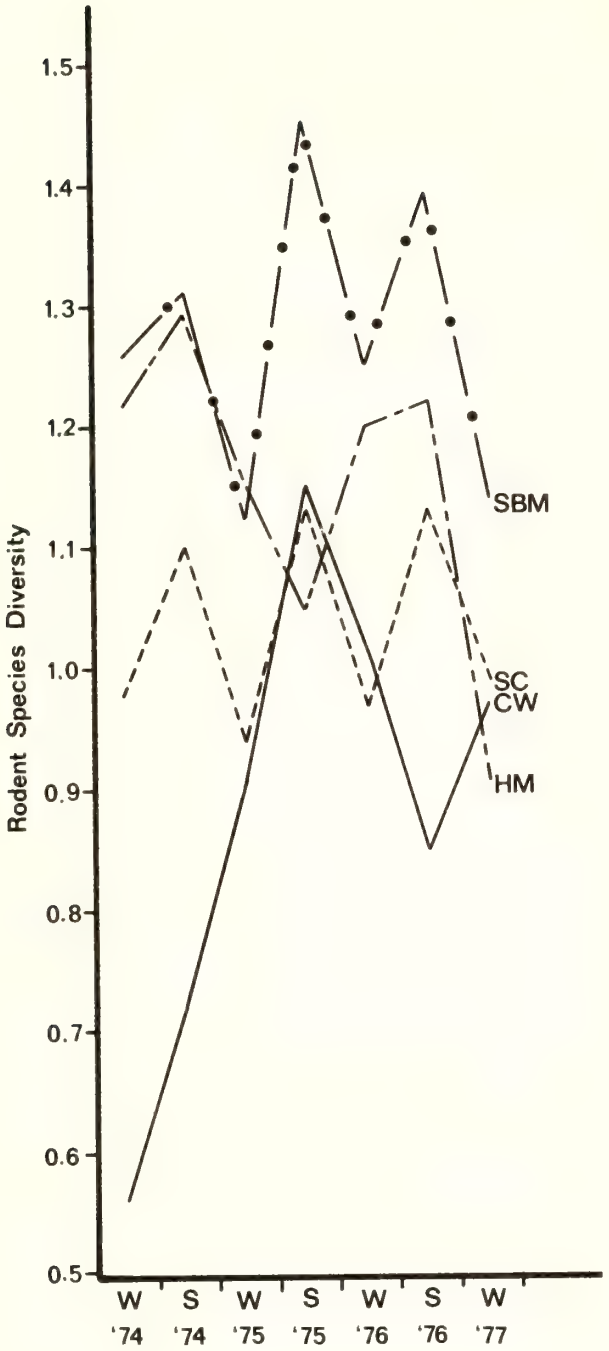


Figure 8.--Densities (N/270tn) of Peromyscus eremicus in four community types in the lower Colorado River Valley.



We thank Jane Durham, Jake Rice, James Bays and Kathleen Conine for critically reading the manuscript. The research was funded through grant number 14-06-300-2415 from the U.S. Bureau of Reclamation.

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Figure 9.--Rodent species diversities in four community types in the lower Colorado River Valley. The diversities are calculated from the average densities (N/270tn) of Peromyscus eremicus, P. maniculatus, Perognathus penicillatus, Dipodomys merriami, and Neotoma albigula caught in a given community type for a given time of year.

Climatological and Physical Characteristics Affecting Avian Population Estimates in Southwestern Riparian Communities Using Transect Counts[1]

Bertin W. Anderson and Robert D. Ohmart[2/]

Abstract.--Comparative data from about 10,000 censuses of line transects on the lower Colorado River show that strong winds (20 to 50 kmph) may reduce censusing accuracy but winds below 20 kmph appear not to strongly influence avian estimates. In winter, optimum censusing time is from 1 hour after sunrise to 2.5 hours after sunrise, whereas in summer the optimum period is 0.25 hours before sunrise to 1 hour after sunup. Consecutive censuses from the same area by highly experienced observers (>5 years of birding) are more consistent than less experienced personnel (10 to 16 months of birding).

Each transect should be censused at least twice monthly for minimum best density estimates and three times for maximum best density estimates and three times for minimum best avian species diversity estimates. Four censuses reveal a greater number of species than with two or three censuses. Number of transects needed for a minimum adequate sample of 3,200 ha of mature honey mesquite (Prosopis juliflora) habitat is four (sampled three times monthly) but for more precise population data for each species six to nine are required.

INTRODUCTION

Since 1973 we have been censusing birds in about 80,000 ha of riparian vegetation in the Colorado River Valley from Davis Dam to the Mexican boundary using the transect count technique (Emlen 1971). Censusing is conducted by 11 full-time observers; the turnover rate among observers being about 25 percent per year. Since the beginning of our study, we have made about 10,000 censuses each 0.8 to 1.6 km in length. With the increased need to determine avian population levels, it is important to quantify the effects of such factors as time of day and wind on censuses. Furthermore, if more than one observer is involved, it is important to know how results from the same area compare. Since the interrelated factors of available time, financial support, and manpower limit the extent of censusing, it is important to know the minimum area in which censusing must be done in order to get reasonably accurate results. Undersampling can lead to erroneous conclusions, while over-sampling is inefficient. This report, although not providing definitive answers, addresses these points and may be helpful to those planning bird censuses in large areas, especially riparian communities in the Southwest.

1/ Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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CLIMATIC FACTORS AFFECTING CENSUSES

Wind

Intuitively it seems that strong wind (20 to 50 kmph) would decrease bird activity and in general interfere with bird detection. In order to quantify this we censused 22 transects on days with winds 24 to 50 kmph and compared the number of detections with the

number made on the same transects on calm days immediately preceding or following windy days. The results (Table 1) are equivocal in that in three of five comparisons involving twelve transects, the number of detections on windy versus calm days were similar; on two occasions involving ten transects, the counts on windy and calm days were dissimilar with significantly greater ($p<0.01$) numbers of detections having been made on calm days. Visual and auditory detections will probably be reduced because birds tend to seek shelter and sounds may be drowned out by wind noises.

Table 1.--Number of bird detections on windy (20-50 kmph) and calm days.

Number of Transects	Detections		Probability of Difference Being Due to Chance
	Windy	Calm	
10	92	93	>0.05
9	59	203	<0.005
1	132	136	>0.05
1	258	259	>0.05
1	196	255	<0.01

In general, if there is a strong wind during the prime census time, we do not begin censusing; but if the winds develop after censusing has begun, we ordinarily finish the transect or set of transects but do not initiate censusing new ones. Winds less than 20 kmph apparently interfere very little with accurate censusing.

Time of Day

Winter censuses (December through January) initiated earlier than one hour after sunrise or later than 2.5 hours after sunrise resulted in significantly ($p<0.05$) fewer detections than those begun 1.0 to 1.5 hours after sunrise. Summer censuses begun between 0.25 hours before sunrise to sunup were significantly ($p<0.05$) greater than censuses begun later than 0.75 hours after sunup (Table 2).

Birds are active earlier and for shorter periods of time in summer than in winter. The often-expressed statement that birds are more active earlier than later at all times of the year and are active for longer periods of time with increasing photoperiod is not supported by data from the lower Colorado River Valley and appears to be an over-generalization. Time of day is, of course, related to temperature (Shields 1977). In summer the censusing can be continued longer on days which are relatively cool, and in winter censusing can be initiated earlier on days which are relatively mild.

In order to census all of our transects monthly, we frequently must begin before and continue beyond the time when birds are most active. To compensate for this we rotate the order in which a set of transects is censused. Shields (1977) indicated that this may be inadequate and significant differences in densities may be obscured. He provided a method for including time of day as a factor in the analysis of variance.

DIFFERENCES BETWEEN OBSERVERS

The relatively large area being studied has dictated the use of 8 to 12 observers. The experience of these individuals is quite varied. Highly experienced observers were those who had been observing birds for several years--sometimes for most of their lives. Others, which we shall refer to as less experienced observers, had not done much bird watching before joining our staff. On the average, the less experienced observers, after training, had been on the job for about ten months.

To determine the extent to which differences in avian densities and diversities vary because of the way observers detect birds, we first evaluated the extent to which observers could reproduce their own results. To make this evaluation three different observers censused a set of transects (4 to 5 km) for four consecutive days. Following this we had five groups of four observers and one group of three observers census about 16 km of transects. Within each 16 km group of transects each observer censused one fourth of the area each day so that by the end of four days each had censused the entire area.

The first part of the test was conducted in April 1977; a difficult time to try to reproduce census results because of the potential for encountering transient individuals of newly arriving summer residents (strictly transient species were not included in the census results). For the three different highly experienced observers, nonsignificant differences in bird density were obtained in 12 of 18 possible comparisons (Table 3). The largest and smallest number of species tabulated differed by four in area 2 and by one in the other areas (Table 3). The largest BSD was 8.1, 9.2, and 11.9 percent above the lowest value in the three areas (Table 3). Thus, the same observer is not always able to reproduce his own results, suggesting day-to-day variation within a given population in an area.

Table 2.--Results of bird censuses taken at different times of the morning in winter and summer in riparian vegetation in the lower Colorado River Valley.

Censusing begun (hours after sunrise)	Number Transects	Totals					
		Detections	Phaino-peplas	Excluding Phaino-peplas	Non-Passerines	Passerines Excluding Phainopeplas	Number Species
Dec. 1974							
1.00	4	175	99	76	10	66	15
1.25	4	191	95	96	33*	63	15
2.00	4	234*	85	149*	64*	85	19
Dec. 1974							
1.50	6	234	149	85	39	46	18
2.50	6	186*	127	59*	30	29	19
Jan. 1975							
1.00	4	194	111	83	31	52	17
1.50	4	255*	119	136*	29	111*	13
1.50	6	179	48	131	30	101	15
2.00	6	166	50	116	30	86	19
Feb. 1975							
1.50	6	113	47	66	18	48	16
1.75	6	121	42	79	20	59	15
July 1974							
-0.25	2	449			292	157	19
1.00	2	308*			199*	92*	17
July 1975							
-0.25	2	294			166	128	20
1.00	2	187*			85*	102	20
June 1975							
0.00	2	328			183	145	19
0.75	2	242*			137*	105*	19

*Significantly different from earlier count at $p<0.01$.

Table 3.--Density estimates for three different areas with about 3.2 km of transects each. Each area was censused by the same observer for four consecutive days.

		Area		
		1	2	3
Density:	Day 1	396	271**	455
	2	411	306**	449
	3	405	374	365***
	4	352*	365	421
Species:	Day 1	25	28	20
	2	23	25	20
	3	24	29	20
	4	24	29	19
BSD:	Day 1	2.502	2.616	2.475
	2	2.405	2.801	2.302
	3	2.480	2.648	2.534
	4	2.205	2.574	2.399

*Significantly smaller than on days 2 and 3 ($p<0.05$).
**Significantly smaller than on days 3 and 4 ($p<0.005$).
***Significantly smaller than on other days ($p<0.05$).

When different observers censused the same transects, significantly different ($p<0.05$) densities were obtained in 18 (60 percent) of 30 possible comparisons between observers of the same transect (Table 4). Test 1 involved two highly experienced and one less experienced observer. The main source of difference was a flock of Chipping Sparrows (Spizella passerina) recorded by one of the highly experienced people but not by subsequent recorders. Test 2 involved four highly experienced recorders. The main difference was in density estimates of White-crowned Sparrows (Zonotrichia leucophrys), a flocking species. Tests 3 and 6 involved three less experienced and only one highly experienced observer and the results varied widely. Results of test 4, involving two highly experienced and two less experienced observers, were fairly similar. Test 5, conducted in desert washes by three highly experienced observers, revealed wide differences in population estimates; but all recorded the same number of species. Significant differences in tests involving two or more highly experienced observers were found in 8 (44 percent) of 18 comparisons. This is significantly fewer than expected based on the results of tests where at least three of the observers were not highly experienced (test 3).

Although some of the differences between observers are significant, they represent population estimates based on a single census. As we shall demonstrate in the following section, differences between observers may be due to this factor more than as a result of different abilities to detect birds. Furthermore, we have already pointed out that the same observer censusing the same area for several consecutive days was not always able to reproduce his own results. With this in mind, the real differences obtained by highly experienced observers in the same area appear quite small, with larger differences resulting when the same area is censused by observers with less experience. The conclusion to be drawn from this is obvious, but in practice it is not always

Table 4.--Six sets of census data obtained by different observers in the same area in the Colorado River Valley.

Test No.	Date/ Vegetation Type/ Area Length	Observer	Total Density	BSD	Total Species
1	21-23 Mar 1975/	1	259	2.66	27
	Honey Mesquite/	2*	209	2.69	27
	8.9 km	3*	216	2.73	25
2	6-9 Nov 1976/	1*	291	2.42	28
	Honey Mesquite/	2*	364	2.41	25
	11.3 km	3*	336	2.67	36
		4*	305	2.71	32
3	6-9 Nov 1976/	1	163	2.39	20
	Salt Cedar, Arrowweed,	2	53	1.97	13
	Screwbean, Willow mix/	3	229	2.36	19
	8.0 km	4*	127	2.51	21
4	6-9 Feb 1977/	1*	255	2.56	22
	Desert Washes/	2*	180	2.38	22
	9.7 km	3	129	2.70	23
5	6-9 Feb 1977/	1*	243	2.29	28
	Honey Mesquite/	2*	286	2.34	32
	11.3 km	3*	248	2.31	31
		4	213	2.51	37
6	6-9 Feb 1977/	1	83	2.59	24
	Salt Cedar, Arrowweed,	2	55	2.26	17
	Screwbean, Willow mix/	3	92	2.13	17
	8.0 km	4*	47	2.46	23

*highly experienced observer

possible to find highly experienced observers when they are needed.

To minimize the possibility that differences between two areas are due to the differences among observers, we schedule censuses so that no individual observer censuses the same transect twice in one month. If this is not possible, only highly experienced personnel census the same area twice.

NUMBER OF CENSUSES REQUIRED

The number of times a transect 0.8 to 1.6 km long must be censused monthly to obtain an accurate population estimate is of crucial importance both for scientific accuracy and to be as economically practical as possible. To acquire insight into this question we censused single transects, groups of three transects (about 3.6 km), and groups of eleven transects (about 13 km) on four consecutive days. The results of the first day are the extrapolated detections obtained on the first day. The totals for the second day represent the mean of the first two days and so on. Species occurring at densities less than 0.5 per 40 ha were dropped from the analysis, thus the number of species sometimes decreased with the addition of a second or third census. Rationale for this procedure is presented elsewhere in these proceedings (Anderson, Engel-Wilson, Wells and Ohmart).

Data for 55 single transects indicate that after the first census there was very little change in the estimated density (Table 5). BSD increased steadily through the fourth census of an area, but the increase (4 percent) with addition of a fourth census was small (Table 5). The number of species increased through the fourth census. Sixteen groups of three transects showed little change in estimated density after the first census; the inclusion of a third and fourth census resulted in very small changes in BSD and number of species (Table 5). Four groups of eleven transects were similarly censused. Once again a third and fourth census of the same area modified the results very little (Table 5). We conclude that if a community type is represented by only one or two transects, censusing should be done at least four times per month. If several transects have been established, two or three censuses appear to yield data as accurate as four censuses. It might be possible to census each area once or twice and to adjust the results by correction factors determined from a larger number of censuses. Such correction factors should be based on a larger data set than we have presented in this report. We have sufficient data to make such an assessment; but for the sake of brevity and because of time constraints, it is not presented here.

NUMBER OF TRANSECTS TO ESTABLISH IN AN AREA

Once it has been determined that there are, for example, 3,200 ha of honey mesquite, the next step is to determine how many transects are needed to obtain an accurate estimate of the population of each species in that area. We established nine transects (11 km) in 3,200 ha of structure type IV honey mesquite. To determine the number of transects necessary to accurately estimate avian populations, a single transect was selected at random, the density and BSD were computed and number of species counted. A second transect was added and new parameters calculated; the new density being the mean of the two transects. From this a new BSD was computed. This randomized process was repeated until all nine transects had been included. If the area was not adequately sampled, the density, BSD, and number of species should have increased or decreased through the ninth census. If a total of nine transects was more than adequate, these parameters should reach a plateau before the addition of the ninth transect. The point at which they level off indicates the number of transects necessary to adequately sample the area. Total density appeared to level off after inclusion of six transects (fig. 1) and BSD and the number of species after the random combination of four transects (fig. 2). On this basis we concluded that four transects rather than nine would have been sufficient in this 3,200 ha area. Three censuses for three transects are apparently as informative as four censuses (see above). For this reason we used data after three censuses from four transects selected randomly from the original nine transects to see if that number was adequate for reproducing the results obtained from all nine transects. Four observers censused the nine transects with each observer having censused all nine once each. This was done in November 1976 and was repeated in February and April 1977.

In November three censuses of four randomly selected transects revealed a density about 19 percent higher and a BSD 2.8 percent lower than that obtained when all nine transects were censused four times each. The two lists contained the same number of species: 24 (89 percent) species were common to both lists; three species occurred on one list but not on the other. These constituted a very small percent of the total density on either list (2.8 percent and 0.7 percent, respectively). Twelve species (44 percent) varied within a range of one individual on the two lists (not

Table 5.-- Changes in estimates of bird population parameters with four censuses of single transects, groups of three transects, and groups of 11 transects.

Number of Groups	Number of Transects Per Group	Number of Censuses	Mean		
			Density (2SE)*	BSD (2SE)	Number of Species (2SE)
55	1	1	249 (42)	1.88 (0.14)	11.7 (1.5)
		2	243 (40)	2.07 (0.12)	15.1 (1.6)
		3	240 (19)	2.15 (0.11)	16.8 (1.5)
		4	239 (19)	2.24 (0.09)	18.7 (1.5)
16	3	1	222 (68)	2.28 (0.17)	17.1 (2.8)
		2	247 (62)	2.46 (0.14)	21.8 (2.8)
		3	246 (60)	2.40 (0.11)	21.5 (2.7)
		4	242 (60)	2.45 (0.10)	22.8 (2.5)
4	11	1	189	2.42	21.3
		2	196	2.72	26.5
		3	195	2.57	23.5
		4	200	2.61	25.0

*Not calculated for groups less than 5.

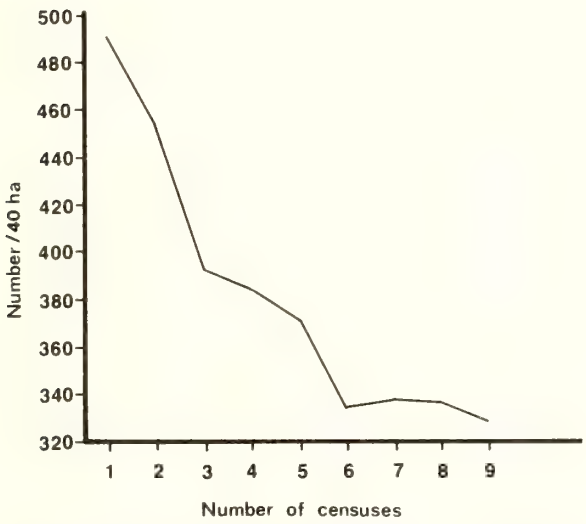


Figure 1.--Changes in avian density estimates with the random additions of transects in 3200 ha of honey mesquite woodland along the lower Colorado River.

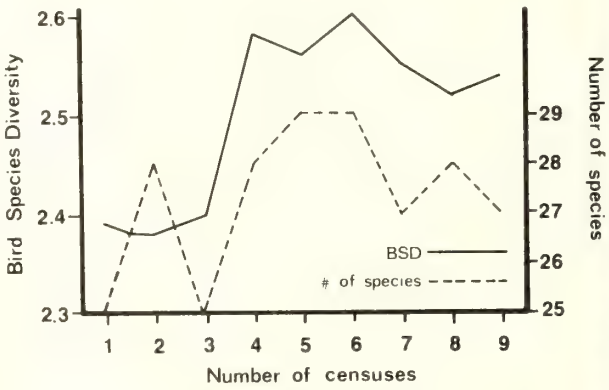


Figure 2.--Changes in the estimates of bird species diversity and number of species with the random addition of transects in 3200 ha of honey mesquite woodland along the lower Colorado River.

counting those cases of a zero (0) on one list and a one (1) on the other). Among the species occurring in densities of 10 or more on at least one list, the average of the four randomly selected transects was about 50 percent higher or lower than when all nine transects were included. Three of the five species varying by over 40 percent were flocking species.

In February three censuses of four randomly selected transects revealed a density 11.2 percent higher and a BSD 4.9 percent lower than that obtained on all nine transects (Table 6). The two lists contained 28 species, 26 of which were common to both lists. Seventeen species (63 percent) varied by only one individual. Those species occurring in densities of ten or more on at least one list varied in density by an average of 31 percent on the randomly selected transects. Both species varying by over 40 percent were flocking species.

In April three censuses of four randomly selected transects revealed a density 5.5 percent smaller and a BSD 2.6 percent larger than that obtained on all nine transects (Table 6). Both lists contained 31 species of which 29 (94 percent) were in common. Twelve species (39 percent) varied by only

Table 6.--Bird densities and diversities in honey mesquite for November, 1976 and February and April, 1977 in the lower Colorado River Valley.

Species	Density (N/40 ha)					
	November		February		April	
	9 transects (4 censuses)	4 randomly selected transects (3 censuses)	9 transects (4 censuses)	4 randomly selected transects (3 censuses)	9 transects (4 censuses)	4 randomly selected transects (3 censuses)
Gambel's Quail, Lophortyx gambelii	9	17	18	26	45	30
Mourning Dove, Zenaida macroura	1	2	12	16	34	29
Roadrunner, Geococcyx californianus	0	0	1	1	1	2
Common Flicker, Colaptes auratus	6	5	1	1	1	1
Gila Woodpecker, Melanerpes aurifrons	3	4	2	1	2	2
Ladder-backed Woodpecker, Picoides scalaris	5	6	3	1	5	8
Yellow-bellied Sapsucker, Sphyrapicus varius	0	0	1	2	0	0
Ash-throated Flycatcher, Myiarchus cinerascens	4	4	1	1	10	13
Say's Phoebe, Sayornis saya	0	0	0	0	1	0
Black Phoebe, Sayornis nigricans	1	1	0	0	0	0
Rough-winged Swallow, Stelgidopteryx ruficollis	0	0	0	0	1	1
Cliff Swallow, Petrochelidon pyrrhonota	0	0	0	0	2	3
Verdin, Auriparus flaviceps	12	14	12	9	18	22
House Wren, Troglodytes aedon	2	2	1	1	2	1
Bewick's Wren, Thryomanes bewickii	6	4	2	1	1	2
Cactus Wren, Campylorhynchus brunneicapillus	4	3	1	0	5	3
Mockingbird, Mimus polyglottos	6	6	7	5	13	11
Crissal Thrasher, Toxostoma dorsale	7	5	3	3	4	6
American Robin, Turdus migratorius	2	0	2	3	1	1
Western Bluebird, Sialia mexicana	5	2	3	2	0	0
Mountain Bluebird, Sialia currucoides	0	1	0	0	0	0
Blue-gray Gnatcatcher, Polioptila caerulea	0	0	0	1	0	1
Black-tailed Gnatcatcher, Polioptila melanura	11	18	8	8	10	8
Ruby-crowned Kinglet, Regulus calendula	20	33	21	22	8	12
Phainopepla, Phainopepla nitens	90	97	89	96	65	64
Loggerhead Shrike, Lanius ludovicianus	2	0	1	0	1	0
Orange-crowned Warbler, Vermivora celata	3	3	3	4	5	3
Lucy's Warbler, Vermivora luciae	0	0	0	0	46	49
Yellow-rumped Warbler, Dendroica coronata	48	43	2	2	24	20
Brown-headed Cowbird, Molothrus ater	0	0	0	0	6	7
Northern Oriole, Icterus galbula	0	0	0	0	0	0
Painted Bunting, Passerina ciris	0	1	0	0	0	0
House Finch, Carpodacus mexicanus	2	1	3	3	0	0
Lesser Goldfinch, Carduelis psaltria	0	0	0	1	1	2
Abert's Towhee, Pipilo aberti	13	23	14	10	15	22
Savannah Sparrow, Passerculus sandwichensis	2	1	0	0	0	0
Sage Sparrow, Amphispiza belli	13	24	6	7	1	3
Dark-eyed Junco, Junco hyemalis	4	2	4	2	4	3
Brewer's Sparrow, Spizella breweri	0	0	1	1	10	6
White-crowned Sparrow, Zonotrichia leucophrys	46	66	27	47	39	24
Lincoln's Sparrow, Melospiza lincolnii	0	0	0	0	0	1
Song Sparrow, Melospiza melodia	0	1	0	0	0	0
Total	327	389	249	277	381	360
SSD	2.54	2.47	2.43	2.31	2.74	2.81
Total Species	27	27	28	28	31	31

one individual. Those species occurring in densities of 10 or more on at least one list varied by an average of 28 percent.

Censuses of the smaller number of transects most frequently included species which did not really use the vegetation type but which were merely occasional visitors for brief periods of time or occurred in some edaphic situation. This was true for the Song Sparrow (Melospiza melodia), Painted Bunting (Passerina ciris), Mountain Bluebird (Sialia currucoides) in November, and the Lincoln's Sparrow (Melospiza lincolnii) in April. On the other hand, scarce species which occurred regularly in a small part of the area being studied tended to be missed with a small number of transects--Loggerhead Shrike (Lanius ludovicianus) in November, February and April; Western Bluebird (Sialia mexicana) and American Robin (Turdus migratorius) in November; Cactus Wren (Campylorhynchus brunneicapillus) in February; and the Say Phoebe (Sayornis saya) in April. It is also clear that species which occurred in densities greater than 10 per 40 ha and which are not evenly distributed were 20 to 50 percent over- or under-represented. The total population estimates, BSD's, and number of species were very similar when either four or all nine transects were used. Four transects censused three times are probably adequate for making general comparisons of overall density, BSD, and number of species in different vegetative types. However, if more precise population data for individual species is desired, more transects are necessary; but two censuses instead of three or more are probably adequate. If availability of time and manpower are severely limited, the smaller number of transects (3 to 6 km) will yield valuable data if censused at least three times monthly.

CONCLUSIONS

Time of day was found to be important in detectability of birds which became active earlier but which have a shorter activity period with increasing photoperiod. If censusing must begin before and last beyond the optimum time, the order in which transects are censused should be arranged so that the same transect is not censused first or last consistently.

Wind potentially reduces detectability and censusing should not begin if there are strong winds (20 to 40 kmph). If winds develop after censusing has begun, the transect or transect set can probably be completed without serious bias; but individual judgment should be exercised in such situations.

For relatively homogeneous areas, up to at least 3,200 ha, four transects totaling about 5 km are probably adequate for useful comparative work. Three censuses per transect per month are adequate. If more precise species by species population data are required, more transects should be established.

ACKNOWLEDGMENTS

We wish to thank the many field biologists who have helped in collecting data. We are grateful to Jack Gildar for computerizing the data. The efforts of the secretarial staff in typing early drafts and of Penny Dunlop and Katherine Hildebrandt in typing the final manuscript are appreciated. Linda Cheney kindly prepared the illustrations. We are grateful to Russell Balda, Jane Durham, Jake Rice, and Kenneth Rosenberg for critically reading the manuscript. The research was funded through a grant from the U.S. Bureau of Reclamation.

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Southwestern Riparian Communities: Their Biotic Importance and Management in Arizona[1]

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Abstract.--The various riparian communities occuring in Arizona and the Southwest are described and their biotic importance discussed. Recommendations are made concerning the management of streamside environments and their watersheds. These include recommendations pertaining to the classification and inventory of riparian habitats; the determination of limiting factors for key riparian species; the establishment of study areas; the regulation and elimination of livestock grazing; the greater consideration of streamside vegetation in authorizing water management projects; and the more conservative use of our watersheds.

INTRODUCTION

No report on riparian habitats would be complete without a discussion of the characteristics and limiting factors of Southwestern riparian vegetation and its associated fauna. These biotic communities have an importance to wildlife and outdoor recreation greatly disproportionate to their limited linear acreage. While man's various manipulations and alterations have resulted in enormous changes in the riparian vegetation, so have his watershed practices affected riparian environments. The long-term effects of past and present land management practices are imperfectly known, but the current situation for many of our riparian communities cannot be termed less than disastrous when compared to conditions of even a short time ago (Freeman 1930, Phillips et al. 1964, Lowe 1964, Jordan and Maynard 1970, Hubbard 1971, Davis 1973, Hinckley 1973, Turner 1974 and others). Some understanding of our remaining riparian communities is therefore necessary if we are to make intelligent judgments about the desirability of future watershed projects in Arizona.

The various riparian communities of Arizona may be represented as formations or vegetation types of forest, woodland, marshland, and even grassland and scrub. A riparian community or association is one that occurs in or adjacent to a drainageway and/or its floodplain and which is further characterized by species and/or life forms different from those of the immediately surrounding non-riparian climax (Lowe 1964). A riparian community may be composed either of constituents peculiar to the riparian situation, or an extension of a higher, climax association fingering downward into the drainageway; the latter type has been termed "pseudo-riparian" (Campbell and Green 1968) to distinguish its faculative nature from the obligate nature of purely riparian species. Examples of pseudo-riparian communities are (1) ponderosa pine (Pinus ponderosa) forests above the Mogollon Rim that follow canyons into the pinyon-juniper woodland, and (2) extensions of some Arizona upland desert scrub species such as palo verde (Cercidium floridum), ironwood (Olneya tesota) and saguaros (Cereus giganteus) in arroyos and along washes within creosote communities in Yuma County. Another regularly observed riparian community of this kind is the extension of encinal or oak woodlands along creeks into plains and desert grasslands in southwestern Arizona.

[1]Paper contributed to the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona

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It is the riparian communities proper, commonly with distinctive plant and animal components not found elsewhere, that are of greatest concern here. This concern stems from their unique character and the resulting changes brought about by modern man, who has reduced and eliminated them at an alarmingly rapid rate. Hopefully an increased awareness and enlightened attitude on the part of public-spirited citizens will prevail and many of the more interesting riparian communities remaining will be available for future enjoyment and study. The following discussion and summary of these riparian communities generally follows the classification outlined in Brown and Lowe (1974).

I. Temperate Deciduous Forests and Woodlands

Warm-temperate, winter-deciduous gallery forest and woodlands, where they still occur, are the most interesting and spectacular riparian communities in Arizona. Originally, interior riparian forests occupied most of the major drainages in the Southwest from the Mohave and Sonoran Deserts through submogollon Arizona, northeastern Sonora, southern New Mexico, northern and eastern Chihuahua to the Rio Grande and its tributaries in southwest Texas. Other, cold-temperate deciduous forests occupy streamsides in montane habitats and in the Great Plains and Great Basin. These forests are maintained along perennial or seasonally intermittent streams and springs and can be divided into two major communities: mix broadleaf and cottonwood-willow. Today only a few drainage systems, such as the undammed Rio Magdalena in Sonora and (to a lesser extent) the San Pedro River in Arizona, present extensive linear riparian forest development. Where streamflows are seasonally intermittent, riparian deciduous forests can be expected only where surface runoff occurs from November through March (Zimmerman 1969, Hibbert et al. 1974) and where the advent of the spring growing season can be expected prior to April 15 (warm-temperate). After mid-April increased evapotranspiration and phytotranspiration may result in only subsurface flow, especially during daytime hours. Summer precipitation usually does not result in sustained streamflow (Zimmerman 1969, Hibbert 1971, Hibbert et al. 1974), and riparian deciduous forests in the Southwest are vernal adapted. As such, Arizona's warm-temperate forests require abundant water during March and April, when most species set seed and germinate (Zimmerman 1969). Probably for this reason, these forests are poorly represented or largely absent from the westerm pediments of the Sierra Madres in southeastern Sonora and Sinaloa, where winter-spring precipitation is less than 25 percent of the total.

Interior mixed broadleaf communities are usually found in Arizona between about 3,500 and 6,500 feet along rubble-bottomed perennial and semiperennial streams (fig. 1). They are



Figure 1.--Interior riparian deciduous forest; mixed broadleaf series along Beaver Creek, Coconino National Forest, Yavapai County, Arizona; ca. 3850 ft., July, 1971. Arboreal associates at this locality in this warm-temperate "gallery" forest are alder, walnut, ash, cottonwoods and willows. Note the luxuriant understory and streamside vegetation without the presence of livestock.

represented in the western portions of the state along Trout, Francis and Burro Creeks in Mohave and Yavapai Counties, through the submogollon region to Rucker and Guadalupe Canyons in southeastern Cochise County. Arboreal constituents may be admixtures or stands of a variety of Holarctic genera consisting of sycamore (Platanus wrighti), ash (Fraxinus pennsylvanica velutina), cottonwood (Populus fremontii, P. angustifolia), boxelder (Acer negundo), alder (Alnus oblongifolia), bigtooth maple (Acer grandidentatum), willow (Salix spp.), walnut (Juglans major), mulberry (Morus microphylla), bitter cherry (Prunus emarginata), and other deciduous species intermingled with oaks and, to a lesser extent, conifers from the adjacent mountains. Arizona cypress (Cupressus arizonica) is not infrequent. Characteristic understory species include brackenfern (Pteridium aquilinum), scarlet sumac (Rhus glabra), poison ivy (Rhus radicans) and the deciduous vines, Virginia creeper (Pathenocissus quinquefolia) and canyon grape (Vitus arizonica).

Several species of wildlife are totally or largely dependent on this community. Among these are the Arizona grey squirrel (Sciurus arizonensis), otter (Lutra canadensis), zone-tailed hawk (Buteo albonotatus), black hawk (Buteogallus anthracinus), water ouzel or dipper (Cincius mexicanus), sulphur-bellied flycatcher (Myiodyrcaster luteiventris), summer tanager (Piranga rubra), Bullock oriole (Icterus bullocki), yellow warbler (Dendroica petechial), Arizona alligator lizard (Gerrhonotus kingi), Sonoran mud turtle (Klinosternon sonoriense), and canyon tree frog (Hyla arenicolor). These communities also provide major habitat types for white-tailed deer (Odocoileus virginianus), black bear (Ursus americanus), turkey (Meleagris gallopavo), as well as a myriad of nesting and migrating raptors and songbirds. Unfortunately, intensive investigations of the populations and nesting densities are lacking for most species of wildlife in this habitat type. An important exception is the lower Gila River in New Mexico where the biota has been inventoried by Hubbard (1977). Lowered streamflow has reduced a number of forests to scattered, individual constituents (woodlands), opening the canopy and presumably reducing its desirability to wildlife dependent on this type. Flash floods, such as the notorious Labor Day flood of September, 1970, have affected many miles of this beautiful streamside forest, and grazing by livestock has reduced the quality of the forest understory almost everywhere, curtailing or eliminating reproduction of some forest species.

Excellent examples of mixed broadleaf forests are still found in Arizona along Wet Beaver Creek above Rim Rock, along Oak Creek in Oak Creek Canyon, along Ash, Redfield, Eagle and Aravaipa Creeks and the San Francisco River. A revitalized forest along Rock Creek on the Three Bar Wildlife Area in the Mazatzal Mountains is especially worthy of mention. In 1959, after the elimination of grazing about 15 years before, the majority of the chaparral watershed burned; subsequent herbicide treatment prevented the rejuvenation of the nonriparian, climax chaparral community, and the sparsely forested vegetation along the drainage was transformed into a dense, excellent representative of mixed broadleaf deciduous forest. The area now provides habitats of importance to black bear and turkey, neither of which had utilized the area before the transformation (Gallizioli 1974). Since the streamflow was transformed from ephemeral to almost perennial prior to the application of herbicides (Pase and Ingebo 1965), the determining roles of fire and range restoration need further consideration.

Forests and woodlands in Arizona dominated by cottonwood and willow (Populus fremonti Salix gooddingii, S. bonplandiana and others) are confined primarily to riparian environments below 3,500 feet on clay or other fine soil and rock deposits [1] (fig. 2). Streamflows are perennial or nearly so. The understory may be a tangle of riparian trees or shrubs or relatively open and parklike. Once extensive, these forests have diminished greatly over the past 100 years with the diversion, interruption and elimination of streamflows. Descriptions taken from accounts telling of the extent of these forests along the Santa Cruz, Gila and Colorado Rivers prior to 1900 are indeed difficult to envision today (Davis 1973). Upstream impoundments, channel cutting, channelization, increased water salinity, irrigation diversions, and ground water pumping have made and continue to make massive inroads on these now relict communities. As in the mixed broadleaf community upstream, cattle grazing has negatively influenced the understory and the quality of remaining stands. Many remaining



Figure 2.--Interior riparian deciduous forest; Cottonwood-willow series along Aravaipa Creek, Pinal County, Arizona; ca. 2800 ft., September, 1968. Willows, principally Salix gooddingii, outnumber cottonwood in this warm-temperate forest and woodland. The principal shrub is seep-willow and because of grazing, the understory vegetation is scant as oppossed to that shown in Figure 1. Photo by Richard L. Todd.

[1] The limited woodlands of cottonwoods (Populus acuminata and others) willows (Salix lasiandra, S. lutea and others) and other deciduous trees north of the Mogollon Rim above 6,000 feet in northeastern Arizona are here considered extreme fasciations of riparian forest other than warm-temperate interior riparian deciduous forest.

mixed broadleaf riparian forests are under the jurisdiction of the U.S. Forest Service, where it is hoped future management of grazing and timber resources will give added consideration to these valuable environments (USFS 1969).

Interrupted examples of cottonwood-willow forests are still found along the Verde, Hassayampa, San Pedro, Bill Williams, Colorado and other rivers. Indications are that these communities are maintained through periodic winter-spring flooding. Stabilized water flows result in decadent stands, in which the dominant species are lacking in reproduction. Cottonwood regenerates itself principally from seed, unlike sycamore and other broadleaf riparian species that reproduce by sprouting, forming clones (Horton et al 1960). Further indications of the subclimax nature of this community are the "new" stands adjacent to portions of the Verde River and Santa Cruz Rivers, which were generated after heavy winter-spring runoffs on these drainages in 1965 and 1967 respectively. The presence of similar fasciations in California also indicates that these forests are vernal-adapted, and that late summer runoff is of little or no benefit to their regeneration.

Studies by Carothers and Johnson (1970) on the Verde River in Arizona have shown the importance of cottonwood-willow forests to breeding birds. More species are recorded as nesting in this vegetation type than any other; in Arizona several species such as the yellow-billed cuckoo (Coccyzus americanus) and blue-throated hummingbird (Lampornis clemenciae) are, for all practical purposes, restricted to it. A comparable study of the nesting birds of a cottonwood-willow community in California showed a similar importance to nesting birdlife (Ingles 1950). The importance of the cottonwood-willow community to avian species including raptors, particularly the black hawk (Buteogallus anthracinus), grey hawk (Buteo nitidus), and bald eagle (Haliaeetus leucocephhalus) is discussed by Todd (1969, 1970, 1971, 1972; Hubbard 1971) and others. The Sonoita Creek Natural Area retained by The Nature Conservancy along Sonoita Creek in Santa Cruz County is an over-mature example of the cottonwood-willow association and a mecca for observers of songbirds and other wildlife. Because of its proximity to Mexico, several peripheral species of birds such as the sub-tropical becard (Pachyramphus agaiae) are regularly observed here. The importance of these communities in maintaining environments for the Southwest's aquatic biota is imperfectly known, but studies by Minckley (1969) on Sonoita Creek and other drainages indicate that they may be of great consequence (also see Miller 1961).

II. Subtropical Deciduous Woodland

The famous mesquite bosques of pre-settlement Arizona are discussed by Brandt (1951), Phillips et al (1964), Lowe (1964), Davis (1973) and others. Unfortunately, the major bosques such as the ones at San Xavier, Komatke (New York Thicket), and Texas Hill are now mostly of historical interest (Brown 1970, 1974; Wigal 1973) (fig. 3). Remnants, some of which are nonetheless excellent examples, still occur along the San Pedro, Santa Maria and Verde Rivers, on the Robbins Butte Wildlife Area adjacent to the Gila River, along the upper middle Gila, and in scattered patches along other Lower Sonoran water courses (fig. 4). While winter deciduous, these bosques are very much subtropical and in Arizona are largely restricted to below 3,500 feet elevation within the Sonoran Desert, where they attain maximum development on the alluvium of old dissected flood plains laid down between the intersection of major watercourses and their larger tributaries (fig. 5).

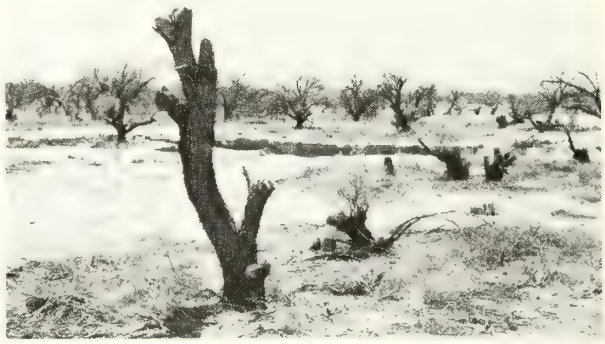


Figure 3.--Subtropical riparian deciduous woodland; remnant of the recently great mesquite bosque at Komatke (New York thicket) near confluence of the Gila and Santa Cruz Rivers, Gila River Indian Reservation, Maricopa County, ca. 1,050 ft., July, 1972. The rapidly dropping ground water table has resulted in this scene of dead and dying mesquites.



Figure 4.--Subtropical riparian deciduous woodland; interior view of mesquite bosque along San Pedro Rivers between Cascabel and Redington, Cochise County, Arizona; May, 1977. The thrifty appearance and abundant reproduction of the mesquites here is in marked contrast to most of the other bosques in Arizona. These bosques are being rapidly cleared for agriculture, however.



Figure 5.--Subtropical riparian deciduous woodland: mesquite bosque community along Gila River below its confluence with Bonita Creek, Graham County, ca. 3,100 ft., December, 1970. Note the sharp contrast between the riparian bosque and the nonriparian Sonoran desert-scrub.

In the past these subtropic woodlands were almost completely dominated by mesquite (Prosopis juliflora velutina), once containing individuals of great size (see e.g., Brandt 1951). Hackberry (Celtis reticulata), screwbean (Prosopis pubescens), and increasingly the deciduous saltcedar or tamarisk (Tamarix chinensis) may now share dominance in local situations (Bowser 1957, Robinson 1965, Turner 1974). As in areas of former cottonwood-willow forest, riparian scrub and marshland, the introduced saltcedar now often exclusively constitutes a disclimax community (fig. 6) at the expense of native plant and animal diversity (see e.g., Phillips et al. 1964, Ohmart 1973).

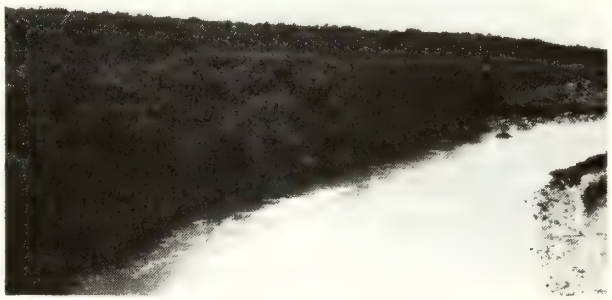


Figure 6.--Riparian deciduous scrubland; a subtropical disclimax consociation along the Salt River in south-central Arizona; September 1958. Scrublands and woodlands of the hybrid saltcedar (Tamarix chinensis) now occupy hundreds of miles of stream channels in the Southwest where they provide important nesting habitats for mourning doves, and in subtropical areas, mourning and white-winged doves.

Historically, saltbushes (Atriplex polycarpa, A. lentiformis), or annual and perennial grasses and forbs formed the ground cover in mature mesquite bosques; the understory was relatively open. Today, introduced annual forbs such as filaree (Erodium cicutartium), mustards (Cruciferae) and grasses, e.g. Cynadon dactylon, Bromis rubens, Schismus barbatus and others, are frequently encountered as understory species. Vines such as janusia (Janusia gracilis), canyon grape (Vitis arizonica), gourds (Cucurbita palmata) and others were, and still may be, conspicuous constituents. Individual cottonwoods, velvet ash and Goodding willow may be interspersed in more mesic sites within the bosque. Greythorn (Condalia lycioides) or a blue palo verde (Cercidium floridum) may occupy an occasional opening or sunny place.

The importance of this woodland type to colonial nesting white-winged (Zenaida asiatica) and mourning (Zenaidura macroura) doves is well documented (Neff 1940, Arnold 1943, Wigal 1973, Carr 1960 and others). Its importance to other avian species is discussed by Brandt (1951), Phillips et al. (1964), Gavin (1972) and others. This community too has suffered greatly from a variety of man-related causes including water diversion, flood control, agricultural clearing programs, and, principally, dropping water tables. This llast factor, including interrupted subsurface flow, has been responsible for the almost total destruction of the mesquite "forests" at San Xavier, Casa Grande Ruins National Monument, Komatke and Texas Hill (Phillips et al. 1964, Brown 1970, Judd et al. 1971).

The continued clearing of other bosques along the Gila and Colorado Rivers has resulted in their replacement by agricultural crops and other type conversions. It has been noted that where intermittent flooding and/or slowly receeding summer surface flow occurs, saltcedar tends to replace mesquite. This is particularly prevalent after the woodlands have been cleared or burned and ground water is close to the surface and water storage facilities and agricultural tracts are present upstream. Whether this replacement is partially due to irreversible changes in water quality and soil chemistry, or is entirely due to the inherent ability of tamarisk to repopulate floodplains rapidly, is a matter for some discussion. [2]

Saltcedar in Arizona has hybridized; it sets seed and germinates throughout the long Southwestern growing season (Horton 1960, Horton et al. 1960), and it is hypothesized that storage facilities which hold back winter-spring runoff and release water irregularly during the summer months favor the establishment of this adventive at the expense of native riparian communties. The aggressive ability of saltcedar to outcompete native riparian species after summer flooding has been well demonstrated by Turner (1974) and Warren and Turner (1975). Nonetheless, saltcedar now provides satisfactory and important nesting sites for mourning and white-winged doves (Carr 1960, Shaw 1961, Wigal 1973 and others). Several thousand acres of federal land along the Gila River, much of which is saltcedar and mesquite, have been withdrawn for these species under Public Law 1015 as the "Fred Weiler Greenbelt". Other areas receiving some degree of protection include the mesquite bosques on the Black Butte Wildlife Management Area, maintained by the Arizona Game and Fish Department, and Tonto National Forest lands along the Verde River. The high demands placed on both mesquite wood and ground water, however threaten all remaining bosques (see e.g., Lacey et al. 1975).

III. Subtropical Evergreen Forest

This complex tropic-subtropic formation has its northern terminus in moist canyons and warm springs in and adjacent to the Sonoran Desert in Arizona and California, where it is represented by stands of California fan palm (Washingtonia filifera). In Arizona native groves--but not all individuals--are limited to two canyons in the Kofa Mountains (Benson and Darrow 1954, Smith 1974), to three sites at end near Alkali Springs in the Hieroglyphic Mountains (Brown et al. 1976) and possibly Cienega Springs near Parker (fig. 7). Because of their miniscule acreage and disjunct occurrence, these communities lack the characteristic vegetational and faunal associates of more southerly subtropic evergreen forests and possess instead distinctive Sonoran oasis associates (Vogl and McHargue 1966, Brown et al. 1976). That these relics of the Miocene and Pliocene remained at all in Arizona was due to the continual presence of abundant subsurface waters in favored tropic-subtropic microenvironments. One also suspects that the adaptibility of this species to alkaline waters may have been a competitive advantage with certain warm temperate forms.



Figure 7.--Subtropical riparian evergreen forest; California fan palm series at Cienega Springs, Yuma County, Arizona. Abundant reproduction frequently characterizes native palm groves in Arizona; the fan palms, tolerant of alkaline waters, have outcompeted their cottonwood-willow competitors over the years at this and other sites.

[2] For a discussion of the salt secretion abilities of saltcedar see Decker 1961.

California fan palms are attractive trees, and their adaptibility to cultivation has made them an ubiquitous ornamental landscape feature throughout the Southwest. The few native communities are considered botantical phenomena to be maintained with a minimum of disturbance. The palms in Palm Canyon, Hidden Canyon and elsewhere have had their shag of dead fronds burned but otherwise appear in good condition, with some reproduction noted. Palm groves and individuals in the Kofa Mountains are within the Kofa Game Range and are under the jurisdiction of the United States Fish and Wildlife Service. The palms at Alkali Springs and Cienega Springs are privately owned.

IV. Riparian Scrublands

While riparian scrub communities cover extensive areas of stream channels and flood plains, scientific investigations and resource managers have generally ignored them and concentrated on the more interesting and diverse communities upstream and downstream. They are, nonetheless, both interesting and important.

Above 8500 feet, a boreal riparian scrub is usually present along subalpine streams and in some wetlands. These scrublands are dominated by scrub willows (Salix bebbiana, S. scouleriana), although red-osier dogwood (Cornus stolonifera), blueberry elder (Sambucus glauca), rocky mountain maple (Acer glabrum) and thin-leaf alder (Alnus tenuifolia) may be locally important, particularly downstream as one approaches and enters more cold temperate conditions (fig. 8). Occasional trees such as blue spruce (Picea pungens) and aspen (Populus tremuloides) may stand out within the scrub. These streamside scrublands are nesting habitat for dusky flycatchers (Empidonax oberholseri), MacGillivary warblers (Oporornis tolmiei), orange-crowned warblers (Helminthophila celata), broad-tailed hummingbirds (Selasphorus platycercus), white-crowned sparrows (Zonotrichia leucophrys) and Lincoln sparrows (Melospiza lincolni). The perennial streams are themselves the habitat of the native Arizona trout (Salmo apache) and the now ubiquitous rainbow (Salmo gairdneri). These stream habitats are subject during the summer months to extensive and intensive livestock grazing, including use by sheep. Stream quality has also been altered by logging activity on adjacent watersheds, a situation which can be expected to increase with the demand for timber resources.

In temperate and subtropic situations in intermittent and perennial stream channels and in and along flood channels one also encounters riparian scrublands (fig. 9). Stream flows in these types are irregular and often occur in the form of flash floods. Dominant species are frequently but not necessarily seepwillow or batamote (Baccharis glutinosa), broom (Baccharis sarothroides or B. emoryi), arroweed (Pluchea sericea), and, increasingly, saltcedar. The reasons for the increase in saltcedar at the expense of the native seepwillow since 1940 have been discussed earlier and are well documented by Horton et al. 1960, Zimmerman 1969, Turner 1974, and Warren and Turner 1975. Riparian scrub may exhibit a dense "chaparral" aspect--scrubland--or present a very open one--desertscrub. Desert willow (Chilopsis linearis), mesquite, catclaw (Acacia greggi) and other arboreal species are frequent associates and may share aspect dominance. These trees as well as those of the riparian deciduous forest, if present, provide less than 15 percent of the ground cover. Faunal relationships within these riparian communities are poorly investigated, but there appears to be a considerable interaction with greater or lesser populations of adjacent or upslope nonriparian species. Bird species particularly well represented in riparian scrub include the Say's phoebe (Sayornis saya), crissal thrasher (Toxostoma dorsale), black-tailed gnatcatcher (Polioptila melanura), phainopepla (Phainopepla nitens) and the brown towhee (Pipilo fuscus). To date, little attempt has been made to "manage" these habitats.



Figure 8.--Montane riparian deciduous scrubland; Mixed series along the North Fort of White River, Fort Apache Indian Reservation; ca. 7500 ft., July, 1977. Prevalent and dominant plants here include two willows, thin-leaf alder, blueberry elder, and hawthorn (Crataegus erythropoda).



Figure 9.--Evergreen riparian scrubland in the channel of the San Carlos River, San Carlos Indian Reservation; ca. 3200 ft., March, 1975. The thick "Chaparral" in foreground is largely seep-willow or batamote. The deciduous scrub is mostly saltcedar. Note the decadent stand of cottonwood along the bank in the distance.



Figure 10.--Saltwater marshland; Saltgrass series at Obed Meadows, Navajo County, Arizona Saltgrass occupies wetland and riparian areas throughout Arizona's subtropic and temperate zones wherever alkaline habitats exist. The deciduous trees in background are the now ubiquitous saltcedar.

V. Marshlands

These wetland formations may be comprised if any of several boreal, temperate or subtropical emergent communities and are defined as aquatic communities, the principal plant constituents of which are emergents not trees, woody shrubs, or nonhalophytic grasses [3], and which normally or regularly have their basal portions annually, periodically or continually submerged. In the Southwest these include communities in both fresh or brackish water environments. They range from the more xeric and alkali communities of salt grass (Distichlis stricta), and alkali bulrush (Scirpus paludosus) through the carrizo or reed communities (Phragmites communis) of the Colorado River and elsewhere to mesic freshwater communities of rushes (Juncus spp.), sedges (Carex spp.). bulrushes (Scirpus spp.) and cattail (Typha spp.) (fig. 10, 11).



Figure 11.--Freshwater marshland; Topock Marsh looking north from north dike, Mohave County, ca. 550 ft. Bullrush and cattail are the principal vegetational constituents in foreground. This famous marsh is one of the few remaining on the Colorado River and is an important breeding area for the Yuma clapper rail. Photo by Richard L. Todd

[3] Riparian grasslands of sacaton (Sporobolus wrightii), tobosa (Hilaria mutica) and other communities, while not discussed, occur in Arizona and the Southwest. See Lowe (1964) for a discussion of tobosa swales. Saltgrass communities are treated here as part of the marshland formation.

These rapidly disappearing communities are found in riparian and littoral situations only where streamflow is turgid, shallow and dependable enough to permit their establishment. Since they are the most mesic of Arizona's vegetational and biotic communities, they have suffered most from the resultant desiccation of the state's natural environment through water diversions and water "management" projects (see e.g., Ohmart ca. 1974). The few riparian marshland communities that remain are habitats for a number of species of Arizona's rare and vanishing wildlife, such as the Yuma clapper rail (Rallus longirostris), black rail (Laterallus jamaicensis), bitterns (Ixobrychus exilis, Botaurus lentiginosus), and Mexican duck (Anas diazi) (Todd 1972a). Numerous other rails, shorebirds, and waterfowl are highly dependent on these diverse environments, both during nesting and migration (Todd 1972a). These marshland oases are now frequently dependent on stored and/or recycled argricultural and industrail waste waters from diverted upstream flow. Examples in Arizona are Picacho Lake in Pinal County and Quigley Pond on the Gila River in Yuma County (see also Brown et al. 1977). Exceptions are a few sloughs and old oxbows of the San Pedro, lower Salt, Verde and Colorado Rivers, almost all of which are threatened by existing or planned projects. It is also an ironic fact that Arizona's most valuable wildlife habitats are too frequently subjected to trampling and grazing by livestock, in addition to hydrological limitations.

VI. Recommendations

It has become increasingly evident that the most valuable and interesting of Arizona's streamside environments are greatly in need of more enlightened management of both the actual riparian communities and the watersheds upon which they depend. Their present limited acreage and importance to endangered, threatened, and peripheral wildlife species have prompted a growing concern by wildlife-oriented groups and individuals in addition to the concern long voiced by professional biologists. This concern has now manifested itself in the political arena and requires that our riparian environments receive greater consideration from resource management agencies.

The following recommendations are suggested to perpetuate and enhance those riparian communities of greatest value to wildlife and public interest:

1. Identify and classify Arizona's riparian environments. Identification and mapping of streamside vegetation is presently either being considered or in the process of inventory by land management agencies, other public agencies, academic groups and ad hoc consultants. These efforts should be coordinated and classifications of the various types determined. A statewide inventory, including maps, of remaining habitats should be prepared and published.

2. Investigate factors determining the limiting specific riparian constituents and communities. The environmental requisities and limits of many of the major riparian plant species must be determined, at least in part. These would of necessity be long-range and continuous studies to provide an understanding of the factors controlling the various communities and their constituents. Only then can we hope to preserve and manage our riparian constituents through regulated discharges of water from reservoirs, selective cutting and other techniques.

3. Establish representative study areas containing all major riparian communities and their surface and groundwater requirements. In addition, as reserves these areas would provide "bench marks" and controls for comparison with "managed" or other "modified" ecosystems.

4. Grazing and other distruptive influences should be eliminated or controlled in riparian forests, woodlands and marshlands. Many of these have had their public values compromised through the degradation of their flora and fauna. Areas presently supporting little or no understory and showing no reproduction of major riparian constituents should be restored where still possible.

5. Riparian and watershed management project planners should reconsider the values both actual and potential of streamside vegetation before irreversible alterations. Several "phreatophyte clearing" projects have resulted in unwarranted destruction of native riparian associations with little or no documented water "salvage" or other claimed conservation measures accomplished (Campbell 1970, Horton 1972, Patrick 1971).

6. Increase the effort to avoid torrential summer and fall flooding through more conservative use of grazing and timbering watershed resources. Shrub invasions of Southwestern watersheds, due to livestock grazing pressures and suppression of fire, have long been documented (see e.g., Leopold 1924, Humphrey 1958). Through proper management, streamflows can be stabilized and increased to the benefit of our riparian resources. These management techniques should be applied now throughout our rapidly deteriorating Southwest riparian wonderland.

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Terrestrial Mammals of the Riparian Corridor in Big Bend National Park[1]

William J. Boeer and David J. Schmidly[2]

Abstract.--Thirty species of terrestrial mammals inhabit riparian habitats in Big Bend National Park (BBNP), but only one species (the beaver, *Castor canadensis*) is restricted to these areas. Major changes in the vegetation during the past 30 years, involving an increase in basal and canopy cover, have resulted in the elimination of at least one species (*Dipodomys ordii*) from the river corridor as well as increased abundance and distribution for two other species (*Sigmodon hispidus* and *Peromyscus leucopus*). Compared to the other major plant communities in BBNP, the rodent fauna of the riparian community has lower evenness, richness, and diversity indices (based on the Shannon-Weaver Index). Human use and trespass livestock grazing are the major impacts acting upon the natural riparian communities in BBNP today.

INTRODUCTION

Mammalian studies of the Big Bend area began with general surveys (Bailey 1905; Johnson 1936; Borell and Bryant 1942; and Taylor *et al.* 1944) designed to identify and document the varied fauna of the area. After the park was established, the perspective of mammalian research changed somewhat and in recent years studies have concentrated on mammalian autecology and synecology (Porter 1962; Dixon 1958; and Easterla 1973). Most mammalian studies have focused on the mammals of the montane woodland and desert grassland habitats. There have been no comprehensive studies of riparian mammals. Baccus (1971) investigated the distribution of rodents in the park with respect to the major physical features, focusing on the effects of the elimination of grazing on the vegetation and the rodent populations. He also described the similarities and dissimilarities of the rodent faunas of the woodland, grassland, and desert shrub communities; however, he divided the fauna of the Rio Grande floodplain between the desert shrub and grassland communities and did not consider the riparian corridor as a unique habitat.

DESCRIPTION OF THE RIPARIAN CORRIDOR

Floodplain or riparian vegetation exists wherever periodic flooding occurs along the Rio Grande in BBNP. These riparian communities vary from areas a few meters (m) wide to areas extending inland a distance of one kilometer (km); furthermore, adjacent arroyos and creeks may carry enough surface or ground water to produce a similar floodplain environment. Topography along the river includes (1) sheer wall canyons (i.e., Santa Elena and Mariscal canyons which rise to elevations of 366 m) with few areas of alluvial deposits; (2) long deep canyons (i.e., Boquillas Canyon) where the walls do not rise abruptly and where larger areas of alluvial deposits occur; and (3) areas of broad flat floodplain with extensive alluvial deposits.

Denyes (1956) recognized three plant associations along the Rio Grande floodplain: (1) the riverbank association, consisting of mesquite (*Prosopis juliflora*), seep willow (*Baccharis* sp.), willow (*Salix gooddingi*), or cottonwood (*Populus palmeri*), located adjacent to areas of exposed silt and coarse gravel at the water's edge; (2) the *Baccharis* association, composed of dense stands of seep willow; and (3) the mesquite association, consisting of a thin line of extensive mesquite trees or an extensive area of several different plant forms. We have found these three associations to be somewhat altered from Denyes' description and, although difficult to document, our general impression is that significant vegetation changes have occurred

[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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in the riparian habitats of BBNP over the past 30 years. The major change is associated with the tremendous increase of salt cedar (*Tamarix chinensis*) along the river. The *Baccharis* association, mentioned by Denyes (1956) as common in the fine sandy loam soils along the river, is recognizable today only at a few places (for example, Black Dike) and appears to have been replaced by a mixed mesquite-salt cedar-bermuda grass (*Cynodon dactylon*) association. Similarly, salt cedar also appears to be replacing native cottonwood and willow trees at many places.

MAMMALIAN FAUNA OF THE RIPARIAN CORRIDOR

Thirty species of terrestrial mammals have been either collected or observed in the riparian habitats of BBNP. These are listed below in checklist fashion with their current status (C = common; U = uncommon; R = rare; E = previously present, but no longer occurs; P = possibly occurs) in the park.

- Pouched Mammals - Order Marsupialia
  - Opossum - Family Didelphidae
    - Virginia Opossum *Didelphis virginiana* - P
- Lagomorphs - Order Lagomorpha
  - Hares and Rabbits - Family Leporidae
    - Desert Cottontail *Sylvilagus audubonii* - C
    - Black-tailed Jack Rabbit *Lepus californicus* - U
- Rodents - Order Rodentia
  - Squirrels - Family Sciuridae
    - Texas Antelope Squirrel *Ammospermophilus interpres* - R
    - Mexican Ground Squirrel *Spermophilus mexicanus* - R
    - Spotted Ground Squirrel *Spermophilus spilosoma* - U
  - Pocket Gophers - Family Geomyidae
    - Yellow-faced Pocket Gopher *Pappogeomys castanops* - C
  - Pocket Mice - Family Heteromyidae
    - Silky Pocket Mouse *Perognathus flavus* - U
    - Desert Pocket Mouse *Perognathus penicillatus* - C
    - Nelson's Pocket Mouse *Perognathus nelsoni* - R
    - Ord's Kangaroo Rat *Dipodomys ordii* - E
    - Merriam's Kangaroo Rat *Dipodomys merriami* - C
  - Beaver - Family Castoridae
    - Beaver *Castor canadensis* - U
  - New World Rats and Mice - Family Cricetidae
    - Cactus Mouse *Peromyscus eremicus* - U
    - White-footed Mouse *Peromyscus leucopus* - C
    - Deer Mouse *Peromyscus maniculatus* - R
    - Hispid Cotton Rat *Sigmodon hispidus* - C
    - Southern Plains Woodrat *Neotoma micropus* - C
  - New World Porcupines - Family Erethizontidae
    - Porcupine *Erethizon dorsatum* - R
- Carnivores - Order Carnivora
  - Dogs and Relatives - Family Canidae
    - Coyote *Canis latrans* - C
    - Gray Fox *Urocyon cinereoargenteus* - U
  - Raccoons - Family Procyonidae
    - Ringtail *Bassariscus astutus* - U
    - Raccoon *Procyon lotor* - C
  - Weasels and Relatives - Family Mustelidae
    - Striped Skunk *Mephitis mephitis* - U
    - Western Spotted Skunk *Spilogale gracilis* - R
    - Hog-nosed Skunk *Conepatus mesoleucus* - R
  - Cats - Family Felidae
    - Mountain Lion *Felis concolor* - R
    - Bobcat *Felis rufus* - U
- Even-toed Ungulates - Order Artiodactyla
  - Peccaries - Family Tayassuidae
    - Collared Peccary (Javelina) *Dicotyles tajacu* - U
  - Deer - Family Cervidae
    - Mule Deer *Odocoileus hemionus* - U

During 1975-1976, we sampled small rodents at 18 different sites along the riparian corridor. Each site was trapped (using Sherman live traps) a total of 720 trap nights resulting in 12,960 trap nights for the entire river corridor. A total of 1,292 rodents representing two families (Heteromyidae and Cricetidae) were captured as follows (number trapped in parentheses): Family Heteromyidae: *Perognathus penicillatus* (896); *Perognathus nelsoni* (2); *Perognathus flavus* (5); *Dipodomys merriami* (65). Family Cricetidae: *Peromyscus leucopus* (162); *Peromyscus eremicus* (19); *Sigmodon hispidus* (70); *Neotoma micropus* (73). *Perognathus penicillatus* was overwhelmingly the most abundant small rodent in the riparian habitats and, for this reason, the total density of heteromyid rodents was greater than that of cricetid rodents. The three other heteromyid rodents were relatively rare along the river, although *D. merriami* was common at a few sites. Densities of the four species of cricetid rodents were more similar to one another than the densities of the heteromyid species. *Peromyscus leucopus* was the most common cricetid and *P. eremicus* the least common; *Sigmodon hispidus* and *Neotoma micropus* occurred in about equal numbers.

Borell and Bryant (1942) also found *Perognathus penicillatus* to be the most abundant rodent in the riparian corridor. However, comparing our data with that of Borell and Bryant (1942) for three other species (*Dipodomys ordii*, *Peromyscus leucopus*, and *Sigmodon hispidus*) reveals that significant changes in abundance and distribution have occurred in these species over the past 30 years. These

differences correlate with major vegetative changes associated with the cessation of extensive livestock grazing. Early accounts (Taylor *et al.* 1944; Sperry 1938) describe the vegetation along the river as open and severely over-grazed. However, since ranching activities ceased at the inception of the park, plant densities seem to have increased greatly so that at several places (e.g., Johnson Ranch) mesquite forests now occur where the river bottom was once open and sparsely vegetated. Extensive fields of grass also occur today at sites (e.g., Smoky Creek and Coyote) which formerly were cultivated and farmed.

Generally, cricetid rodents prefer habitats with considerable ground cover. Thus, the increased density of grass and cane (*Phragmites communis*) along the riparian corridor, as a result of the elimination of grazing, has served to substantially increase suitable habitat for these rodents. Two cricetines (*Sigmodon hispidus* and *Peromyscus leucopus*) exemplify this trend. Borell and Bryant (1942) collected only four specimens of *Sigmodon hispidus* along the river among the cane and cultivated fields around the Johnson Ranch. We recorded 70 cotton rats from 12 different localities along the river in areas where thick bermuda grass, cane, and fleabane (*Erigeron* sp.) were present. Similarly, Borell and Bryant (1942) reported taking a few *Peromyscus leucopus* along the river from one mile SW Boquillas and the Johnson Ranch. Our trapping records indicate that *P. leucopus* is now one of the most common rodents of the riparian corridor and this mouse occurs all along the river from the mouth of Santa Elena Canyon to Rio Grande Village.

Ord's kangaroo rat (*Dipodomys ordii*) is a species which apparently has completely disappeared from the riparian corridor during the past 30 years. This species was first reported from BBNP in 1939 by M. D. Bryant who described a distinct subspecies (*D. o. attenuatus*) from the mouth of Santa Elena Canyon. In 1944, Dr. William B. Davis (pers. comm.) collected two specimens from the type locality and another from the Johnson Ranch. There have been no additional specimens captured along the Rio Grande since then, although Baccus (1971) trapped at the mouth of Santa Elena Canyon, the Johnson Ranch, and other sites along the river. In over 13,000 trap nights along the river, including efforts at the type locality and the Johnson Ranch, we failed to capture a single *D. ordii*. Baccus (1971), however, did obtain a few specimens from Upper Tornillo Creek Bridge (16 km NE Panther Junction), and this apparently represents the only remaining population of this subspecies in BBNP.

In order to ascertain the status of *D. o. attenuatus*, we spent eight days (from 4 April 1976 to 12 April 1976) trapping at Upper Tornillo Creek Bridge and other places where this species had been previously collected. Initially, 70 traps were set on both the east and west side of Upper Tornillo Creek. Later, the number of traps was increased to 110 on the west side and 160 on the east side. The traps were set out in various soil and vegetation types ranging from deep sand-sparse burro-brush (*Hymenoclea monogyra*), to packed sand-mesquite and gravelly-creosote (*Larrea divaricata*) flats. A total of 18 *D. ordii* and 21 *D. merriami* were caught during the first two nights of trapping. Thirty traps were also set at Lower Tornillo Creek Bridge and 120 were placed along Terlingua Creek where it enters the mouth of Santa Elena Canyon. Most of the Lower Tornillo Creek area was a creosote flat with clumps of catclaw (*Acacia greggii*) and lechuguilla (*Agave lechuguilla*) next to the creek bed. The dry creek bed itself was very rocky and surrounded a small knoll of deep sand covered with little vegetation. Eight traps were placed on this knoll and 22 in the surrounding flats adjacent to the creek bed. A single *D. ordii* was captured on the knoll and nine *D. merriami* were captured on the flats. At Terlingua Creek, the traps were placed in a sandy area and 10 *D. merriami* were captured.

A trapping grid established at Upper Tornillo Creek consisted of 10 lines of 40 traps per line with each trap 18 m apart; each line was 36 m apart. With regard to vegetation and soil, three distinct habitats (designated A, B, and C) were delineated on the grid. Habitat A was on the first floodplain stage adjacent to the creek and consisted of a very open area of deep sandy soil with burro-brush and a few desert willow (*Chilopsis linearis*) comprising the dominant vegetation. Habitat B included the second floodplain stage and consisted of a sandy but more compact soil with a moderate cover of vegetation including creosote, whitethorn (*Acacia constricta*), mesquite, burro-brush, grass, and prickly pear (*Opuntia* sp.). Habitat C was located on a bench about 3-4 m above habitats A and B. The soil was very compact and the vegetation moderate to thick. Typical desert vegetation, consisting of clumps of mesquite, prickly pear, allthorn (*Koeberlinia spinosa*), creosote, and tasajillo (*Opuntia leptocaulis*) were interspersed throughout habitat C.

The total number of captures of *D. ordii* and *D. merriami* for each of the 10 trap lines is presented in Table 1. The percentage of captures of *D. ordii* for each of the three habitat types was as follows: habitat A, 66.1%; habitat B, 30.6%; habitat C, 3.2%. Thus, *D. ordii* was most common in the deep,

Table 1.--Four day capture totals by trap line for *Dipodomys ordii* and *Dipodomys merriami* at Upper Tornillo Creek Bridge.

Habitat type	Trap line	Total captures	*D. ordii* captures	*D. merriami* captures	Percent *D. ordii*	Percent *D. merriami*
A	1	29	25 (40.3)[1]	4 (5.8)[1]	86.2	13.8
	2	20	16 (25.8)	4 (5.8)	80.0	20.0
B	3	11	3 (4.8)	8 (11.6)	27.3	72.7
	4	10	5 (8.1)	5 (7.2)	50.0	50.0
	5	18	7 (11.3)	11 (15.9)	38.9	61.1
	6	11	1 (1.6)	10 (14.5)	9.1	90.0
	7	8	5 (8.1)	3 (4.3)	62.5	37.5
C	8	19	0	19 (27.5)	0.0	100.0
	9	5	0	5 (7.2)	0.0	100.0
	10	0	0	0	0.0	0.0

[1]Represent percent of total catch of *D. ordii* or *D. merriami* in a particular trap line.

sandy and sparsely vegetated areas of the first floodplain stage and decreased in number in habitats away from the creek bottom. The percentage of captures of *D. merriami* for each of the three habitat types was: habitat A, 11.6%; habitat B, 50.7%; and habitat C, 37.7%. Thus, *D. merriami* was more generally distributed throughout the three habitats but was much less common in habitat A where *D. ordii* dominated. *D. merriami* seemed to prefer areas where the soil was more compact or gravelly and the vegetative cover was greater.

Dr. William B. Davis trapped at the Johnson Ranch and the mouth of Santa Elena Canyon in the early 1940's and his description of the vegetation there is completely different from what these areas are like today. According to Davis (pers. comm.), the river bank at the Johnson Ranch was a very open sandy area and was used as a river crossing point for Mexicans and cattle. The mouth of Santa Elena Canyon, according to Davis, was also a sandy, open area with a considerable growth of *Baccharis*. Davis collected Ord's kangaroo rat at both of these locations. Today, the Johnson Ranch and the mouth of Santa Elena Canyon are more like mesquite forests with very little open terrain. In over 1,500 trap nights at these two locations, not a single *D. ordii* was captured, although 15 *D. merriami* (two at Johnson Ranch and 13 at the mouth of Santa Elena Canyon) were collected. In fact, after examining the entire riparian corridor in BBNP, the only place which seeminly had suitable habitat for *D. ordii* was the Gaughing Station. Trapping at this site (720 trap nights), however, produced 15 *D. merriami* and no *D. ordii*. *D. ordii attenuatus* now seems to be confined to the first and second floodplain stages of Tornillo Creek in BBNP and no longer occurs along the river or at the type locality.

Another mammal affected by vegetative changes in the riparian corridor is the beaver which, more than any other mammal in BBNP, is dependent on the riparian corridor for food and shelter. Beaver along the Rio Grande utilize a variety of plants including cane, seepwillow, willow, and cottonwood. Cottonwoods occur today only in park service nurseries at Rio Grande Village and Cottonwood Campground; salt cedars are rapidly replacing cottonwoods and willows at other sites. For example, the Gauging Station is one of the few areas where extensive stands of willow still exist, and these are currently being used as a food source by beavers. Nowhere along the river corridor is there any evidence of beaver using salt cedar. As a result, beavers are literally eating themselves out of "house and home" because they utilize willow saplings for food and leave only salt cedar saplings which they will not use. Taylor *et al.* (1944) reported a beaver population of approximately 100 individuals for the river corridor. However, conversations with park personnel and the evident lack of beaver sign along most of the river indicate the beaver population today is well below the figure reported by Taylor *et al.* (1944).

The Shannon-Weaver Index of Diversity (Odum 1971) was used to compare the rodent fauna of the riparian community with that of the woodland, grassland, and desert shrub communities in BBNP. This index reveals information concerning the stability of a community in terms of its fauna. Compared to the other plant communities, the riparian community has the lowest evenness, richness, and diversity

Table 2.--Shannon-Weaver Index of diversity for the terrestrial rodent fauna of the four major plant communities in BBNP.

Parameters	Communities			
	Riparian[1]	Desert-shrub[2]	Grassland[2]	Woodland[2]
Diversity ($\bar{H}$)	1.157	2.008	2.249	1.849
Evenness (e)	.465	.783	.793	.771
Richness (d)	1.523	1.854	2.912	1.596
No. of Species	12	13	17	11

[1]Data from Schmidly *et al.* (1976a, table 20, p. 94).

[2]Data from Baccus (1971, table 10, p. 49).

indices (Table 2). In particular, the evenness value (0.465) for the riparian community is considerably lower than that of the other communities, indicating that one or two species tend to dominate the rodent fauna of this community. This is evident when examining the total catch figures along the riparian corridor. The two dominant species of the riparian community are *Perognathus penicillatus*, with a total of 924 individuals or 67.7% of the total catch, and *Peromyscus leucopus*, with a total of 162 individuals or 11.9% of the total catch. The grassland is the most diverse community, having the highest diversity, evenness, and richness indices as well as the greatest number of species (17). The desert-shrub, although it only has 13 species (one more than the riparian community), is a more diverse community because it has a more even distribution, which is indicated by the fact that the dominant species (*Perognathus penicillatus*) in this community accounts for only 38.6% of the total catch as compared to 67.7% for the riparian community.

IMPACTS IN THE RIPARIAN CORRIDOR

In recent years, many riparian areas along the Rio Grande have been impacted by human activity. Around El Paso and Presidio, man has destroyed or greatly altered natural riparian natural habitats through water salvage, cultivation and grazing. The International Boundary and Water Commission is presently considering a boundary restoration project along the Rio Grande from Fort Quitman (Hudspeth County) to Presidio (Presidio County). This project would straighten the channel of the river and result in the virtual destruction of riparian habitats along this stretch of the Rio Grande.

Human use (floating and camping) and trespass livestock grazing are the major impacts acting upon the natural riparian communities in BBNP today. In 1975 the Rio Grande accounted for 49% of the total backcountry use (in man-days) in BBNP (Ditton *et al.* 1976). Twenty-five percent of this use was float trips on the Rio Grande and 24% involved camping at primitive sites along the River Road. Schmidly *et al.* (1976b) used correlation analysis to investigate the relationship among human use, impacts, and biological parameters (i.e., rodent fauna and vegetation) at 18 riparian sites in BBNP. Their results revealed a positive and significant relationship between total subjective human impact ratings and annual camping use by site (man-days). However, the extent of human impact did not correlate significantly with rodent densities or vegetative parameters at the 18 sampling sites. Thus, correlation analysis revealed that site impacts have occurred as a result of recreational use, but not to the point where ecological conditions, as indicated by the biological health of the rodent fauna and vegetation, are in jeopardy (Schmidly *et al.*1976b).

Domestic mammals also occur in the riparian corridor and pose a major problem. The increase in grasses over the past 30 years has provided forage that is not available in the same quantity or quality across the river in Mexico. As a result, trespass livestock from Mexico are invading the riparian corridor in increasing numbers. Grazing by trespass livestock is a constant feature of almost all riparian sites and is not confined to one particular region or section of the river. Should this grazing activity continue to increase, it could have dangerous repercussions on the existing vegetation of the riparian corridor. Hence, dealing with the livestock problem may prove more difficult for park managers than dealing with human use and impacts which tend to be concentrated in some areas and virtually absent in others.

CONCLUSIONS

Analysis of small mammals, vegetation,

and impacts along the Rio Grande in BBNP has led to five important conclusions: (1) Major vegetative changes (including the replacement of cottonwoods and willows by salt cedar as well as a tremendous increase in basal and canopy cover) have occurred over the past 30 years. (2) These vegetational changes have resulted in an alteration of the rodent fauna so that certain species which were once rare in riparian habitats (i.e., cricetids such as *Sigmodon hispidus* and *Peromyscus leucopus*) have increased their numbers and ranges along the river, whereas other rodents which were once common (i.e, *Dipodomys ordii*) no longer exist in the riparian corridor. (3) The increase in vegetative cover, especially grasses, has caused a reinvasion of domestic livestock (trespass livestock from Mexico) into the riparian corridor and this may have potentially serious repercussions on the vegetation. (4) Impacts at certain riparian sites have occurred as a result of recreational use, but not to the point where ecological conditions are in jeopardy. Human impacts seem to be confined to areas of convenient access. (5) The riparian community (as revealed by Shannon-Weaver Index) is less stable than the other major communities in BBNP and possibly would be more susceptible to greater oscillations resulting from increased impacts (either human or livestock).

ACKNOWLEDGMENT

This paper is based on research conducted by the authors as part of research contract No. CX70050442 for the Office of Natural Resources, Southwest Region, National Park Service, Santa Fe, New Mexico.

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Twelve presented and 15 contributed papers highlight what is known about this unique, diminishing vegetative type: characteristics, classification systems, associated fauna, use conflicts, management alternatives, and research needs. Speakers stressed the continuity and interrelationships of riparian ecosystems, their wildlife and vegetation, historic and current uses.

Keywords: Riparian habitat, endangered habitats, aquatic ecosystems.

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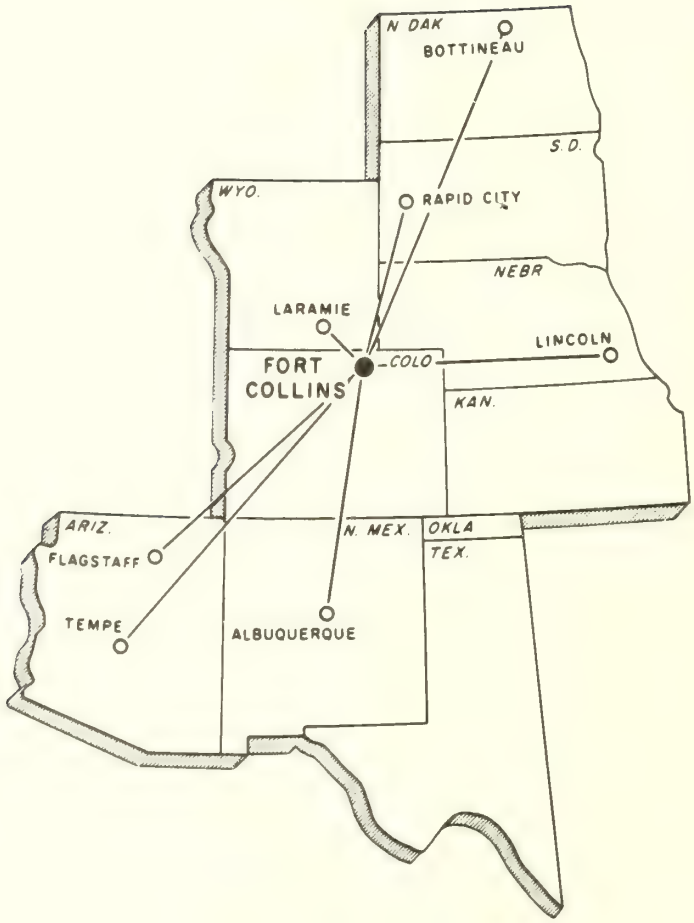
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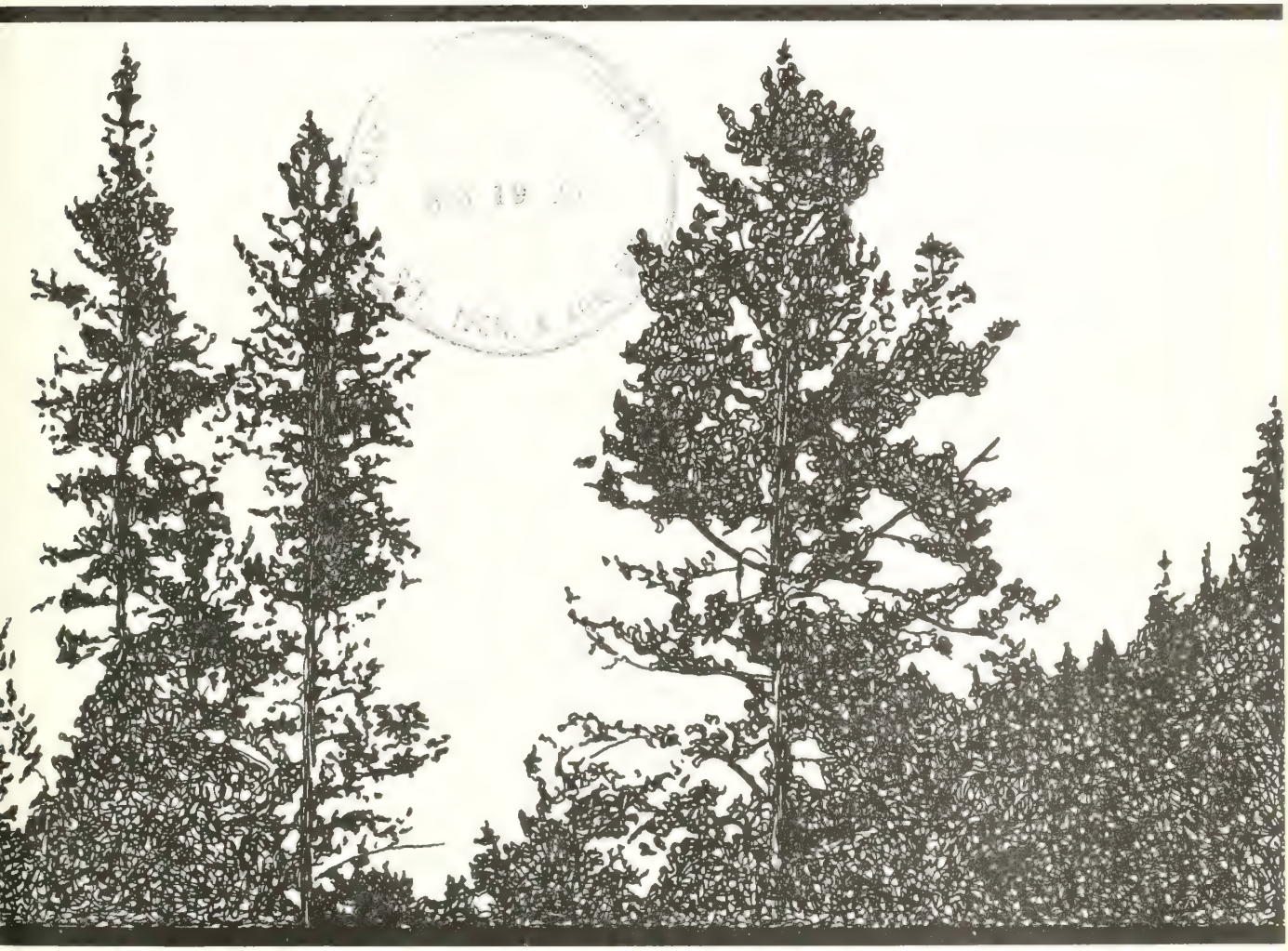
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Characteristics of Arizona Ponderosa Pine Stands on Sandstone Soils

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U.S. Department of Agriculture
Fort Collins, Colorado 80521

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November 19

Characteristics of Arizona Ponderosa Pine Stands on Sandstone Soils

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Abstract

Limited information is available for ponderosa pine forest types growing on sedimentary-derived soils. Based on a 4-year study of ponderosa pine watersheds on sedimentary soils, annual water yield is about 25% of that from volcanic soils, herbage production is lower even though forest densities are less, and forest site index is higher.

[1]*Central headquarters is maintained at Fort Collins, in cooperation with Colorado State University. Baker is located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University.*

Characteristics of Arizona Ponderosa Pine Stands on Sandstone Soils

Peter F. Ffolliott and Malchus B. Baker, Jr.

Introduction

In the Salt-Verde River Basin, an area that provides many natural resources and uses to central Arizona, about 57% of the ponderosa pine[2] forest type grows on volcanic-derived soils. The remaining 43% occurs on soils derived from sedimentary materials (Baker and Brown 1975, Ffolliott et al. 1972). Most of the available information about ponderosa pine ecosystems has been obtained on volcanic soils with only limited work on sedimentary soils. To get more complete information, the Heber watersheds were established in 1972 as a cooperative project between the USDA Forest Service and the University of Arizona.

In 1972-73, stream gages were built on two small watersheds, 60 acres (24.3 ha) each, on soils derived from sandstone, located near Heber in central Arizona (fig. 1). Precipitation gages and a hygrothermograph were also installed. Streamflow was measured on each watershed, and sediment, water quality, timber, range, and wildlife were sampled. Data are based on 4 years of record from water year 1973 through 1976.

This report describes present physiographic, hydrologic, and biotic characteristics of the Heber watersheds. The information obtained on the watersheds has been combined for this presentation. General comparisons also are made between these characteristics and those previously developed for ponderosa pine forests on volcanic soils.

[2]*Scientific names of plants and animals mentioned in the text are listed at the end of this report.*

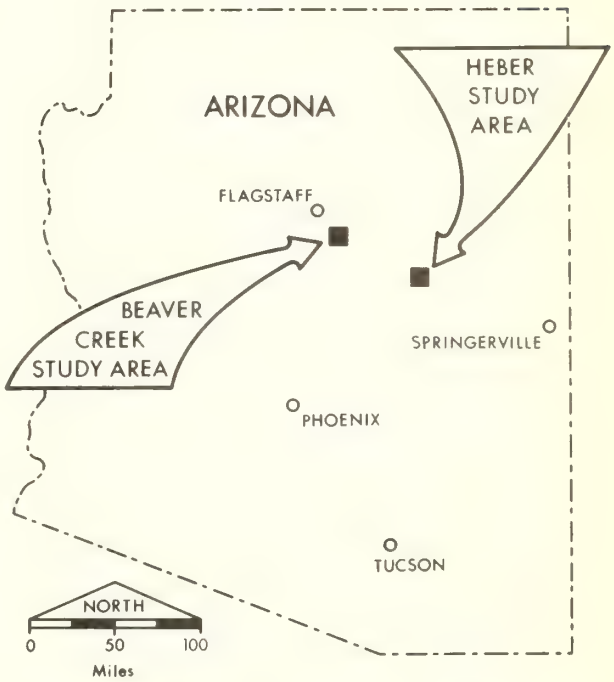


Figure 1.—The Heber and Beaver Creek watersheds. The latter areas occur on volcanic soils.

Present Land Management

Present management on the Heber watersheds is similar to that on surrounding ponderosa pine forests growing on sedimentary soils. The forest overstory has been cut over. The most recent harvest using group selection cutting removed approximately 40 to 50% of the merchantable sawtimber. No timber has been cut on the watersheds since the early 1960's.

The area has been under intensive fire protection since the early 1900's. However, occasional wildfires, caused mostly by lightning, have burned portions of the area. In addition, slash has been piled and burned after recent timber cuttings.

Herbage produced under the forest overstories provides summer forage for cattle under a rest-rotation grazing system. However, less than 25% of the herbage produced annually is normally consumed.

The Heber watersheds furnish seasonal habitat for mule deer, elk, Merriam's turkey, Abert squirrel, and cottontail. Many nongame species of wildlife are also found.

Hunting, camping, and other casual recreational activities are common throughout the area, which is quite accessible from the metropolitan centers of central Arizona.

Physiography

The watersheds exhibit the relatively flat topography common on the Colorado Plateau, with few slopes over 10%. Elevations range from 6,800 to 7,000 feet (2,073 to 2,134 m). Cretaceous undivided material, unnamed but with mineralogy similar to that of the Coconino sandstone formation, lies beneath the watersheds. Soils developed from this material are in the McVickers series, with fine, sandy loam surface textures.

Hydrology

Temperature

Annual temperature regimes are similar to those observed in other Arizona ponderosa pine forests (Schubert 1974). Annual temperature measured adjacent to the watersheds is 49°F (9°C).

Precipitation

The watersheds receive an average of 21 inches (53.3 cm) of precipitation annually, an amount commonly associated with Arizona ponderosa pine forests (Schubert 1974). The averages were determined from precipitation gages located on and adjacent to the watersheds.

Two major precipitation seasons characterize the area (fig. 2). Sixty-five percent of the precipitation falls from October through April. The remainder falls primarily in July through early September.

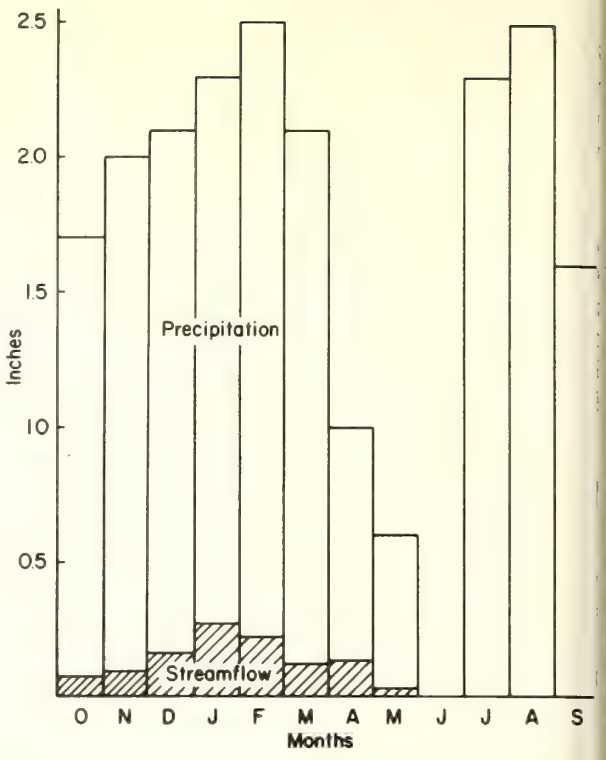


Figure 2.—Comparison of average annual precipitation and streamflow on the Heber watersheds.

Most of the streamflow originates as snowmelt runoff. However, as is common throughout the ponderosa pine forests in Arizona, the snow regime is quite variable. For example, peak seasonal water-equivalents in 1972-73, a year of record snowfall in Arizona (Barnes et al. 1974), averaged 7.5 inches (19.0 cm). In 1974-75, it averaged 1.2 inches (3.0 cm).

Streamflow

Streamflow was measured by 3-foot H flumes instrumented with digital stream stage recorders at the mouth of each watershed.

Annual streamflow measured at the flumes has varied from 0.02 to 5.0 inches (0.05 to 12.7 cm), with an average of 1.1 inches (2.8 cm) per year.[3] Ninety-eight percent of the annual streamflow occurs from October through April as a result of snowmelt or winter rains. Summer storms, while often intense, rarely produce runoff (fig. 2).

[3]*On one watershed, only a 3-month streamflow record is available for WY 1972-73.*

Approximately 5% of the annual precipitation becomes streamflow. From October through April, streamflow is 8% of precipitation; from May through September, it is only a trace.

Since streamflow depends upon the snow regime, snowmelt runoff efficiency — that portion of the snowpack on-site that is converted to measurable runoff — is an important hydrologic characteristic. Snowmelt runoff efficiencies on these watersheds are relatively low, less than 15% (Solomon et al. 1975).

Sediment and Water Quality

Samples of water were collected at the mouths of the watersheds at time of runoff to describe water quality, both physical and chemical.[4] Collections were taken to coincide with weekly instrument maintenance.

Suspended sediment concentrations and chemical quality characteristics of the streamflow are summarized below; pH ranged from 6.6 to 8.1.

Constituent	Range (mg/l)
Suspended sediment	3-181
Total soluble salts	23-99
Bicarbonate	14-44
Calcium	3-10
Carbonate	0
Chloride	1.4-13
Fluoride	0.02-0.16
Magnesium	0.30-0.75
Nitrate	0.03-0.75
Sodium	1-5
Sulfate	1-60

Timber

The forest overstory is uneven-aged stands of cut-over ponderosa pine with intermingling Gambel oak and alligator juniper. The average site index is 77 (Minor 1964).

[4]*This phase of the study was supported, in part, with funds provided by the U.S. Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379.*

Trees were inventoried on the two watersheds. A systematic set of thirty 0.1-acre (0.04 ha) plots was established on each watershed. All trees on each plot were tallied, and four trees from each plot were measured for height, diameter, age, and growth.

The forest overstory statistics are listed below:

	Basal area per acre (ft^2)	Volume per acre (ft^3)
Ponderosa pine	57	1,482
Gambel oak	7	136
Alligator juniper	1	13
Total	65	1,631

Ponderosa pine sawtimber averages 6,888 fbm per acre, with less than 5% in grade 3 or better (Gaines 1962).

Annual growth of the ponderosa pine stands averages 35.6 cubic feet (2.5 m^3/ha) and 136 fbm per acre as estimated by stand table projections (Ffolliott 1965).

Number of trees per acre is an important characteristic of a forest stand. The distribution of number of trees per acre by diameter class indicate an uneven-aged ponderosa pine stand structure (table 1).

Table 1.—Average number of trees per acre, by species and diameter size class (inches d.b.h.), on the Heber watersheds

Diameter class	Ponderosa pine	Gambel oak	Alligator juniper	All species
Midpoint				
2	18.34	0 17	1.10	19.52
4	22.01	67	.67	23.35
6	17.67	2 01	33	20.01
8	11.83	1.33	50	13.66
10	6.17	1 00		7.17
12	3.16	83		3 99
14	3.67	.33		4 00
16	2.33	.50		2.83
18	1.83	.33		2.16
20	2.87	.67		3.54
22	2.76	.33		3.09
24	2 38	.17		2.55
26	1.17			1.17
28	63		.16	.79
30	.67		.17	.84
32	.38			.38
34				
36	.17			17
Total	98.04	8.34	2 84	109.22

Timber quality, as indexed by stem characteristics and defect features that influence the recovery of primary wood products (Barger and Ffolliott 1970), is similar to that observed in cutover ponderosa pine forests in Arizona.

Range

Total herbage production averages 104 pounds per acre (116 kg/ha), consisting of 53 pounds (50 kg/ha) of perennial grasses, 32 pounds (36 kg/ha) of forbs and half-shrubs, and 19 pounds (21 kg/ha) of shrubs. Principle grasses and grasslike plants include mutton bluegrass, blue grama, bottlebrush squirreltail, Arizona fescue, black dropseed, and sedge. Forbs are showy aster, showy goldeneye, western ragweed, and broom snakeweed. Shrubs, in addition to Gambel oak, include New Mexican locust and ceanothus.

The range inventories involved plot measurements of herbage production and utilization. On each of the watersheds, 30 clusters of three 9.6-square foot (0.9-m^2) plots were established. Herbage production was determined by weight estimate and checked by clipping and weighing (Pechanec and Pickford 1937a). Utilization was measured by the ocular-estimate-by-plot method (Pechanec and Pickford 1937b).

Forest Floor

The forest floor, defined as the accumulation of dead organic matter above mineral soil, affects the hydrologic cycle, tree regeneration, herbage production, and fire behavior. Total forest floor depths and weights average 1.0 inch (2.5 cm) and 7.0 tons per acre (15,680 kg/ha) respectively, with the greatest accumulation in the well-decomposed H layer (Ffolliott et al. 1976). Empirical equations for predicting forest floor depths and weights from timber basal area are similar to those developed on volcanic soils (Ffolliott et al. 1968).

Wildlife

Wildlife use has been estimated from counts of deer, elk, and cottontail fecal droppings. In addition, occurrence of browse was recorded to assess habitat quality.

Assuming one pellet group per acre per month is equivalent to 1.5 deer or elk per square mile (Neff 1968), deer and elk populations, as calculated from 1973-76 data, averaged 6 and 1.5 per section, respectively.

Estimates of cottontail populations, derived from a defecation rate of 475 pellets per day, ran as high as 14 per section (Costa 1976). The highest densities were found where ponderosa pine regeneration provided sufficient food and cover (Costa et al. 1976).

Frequencies of occurrence of browse species tallied on 1/100-acre (0.004 ha) plots, 5 feet (1.5 m) high, were:

	Percent
Ponderosa pine	87
Gambel oak	32
Ceanothus	24
Alligator juniper	5

Comparisons With Ponderosa Pine Forests on Volcanic Soils

Since ponderosa pine forests in Arizona are found on both sedimentary soils, such as on the Heber watersheds, and volcanic soils such as those on the Beaver Creek watershed (fig. 1), a comparison of hydrologic and biotic characteristics for the same time period may be useful to land managers.

While temperatures and precipitation regimes on the Heber and Beaver Creek watersheds are similar, average annual runoff measured at the flume on the latter is approximately four times the runoff from the former. More than 90% of the streamflow from both areas occurs from October through April.

Snowmelt runoff efficiencies on the Heber watersheds are lower than those on the Beaver Creek watershed (Solomon et al. 1975). Efficiencies on sandstone soils were less than 10% in 1972-73; corresponding efficiencies on the volcanic soils ranged from 45 to 90% for the same time.

Suspended sediment concentrations and average values of dissolved chemical constituents on the Beaver Creek watershed (Brown et al. 1974) are similar to those observed on the Heber watersheds.

The forest overstory on the Heber watersheds is less dense than on Beaver Creek (Brown et al. 1974). This difference is due partly to different timber cutting histories on the two areas. However, growth rates at Heber are greater than those estimated on Beaver Creek. Forest densities were less on the Heber watersheds, and, therefore, individual tree growth rates were higher. Site index on the sandstone soils averaged 77, but only 60 on the volcanic soils.

Excluding reproduction, there are fewer trees in all size classes on the Heber watersheds than on the Beaver Creek watershed (Brown et al. 1974). However, the density of reproduction was approximately twice as great on the sandstone soils. Openings in Arizona ponderosa pine stands on sedimentary soils are more commonly characterized by dense reproduction than are openings in stands on volcanic soils (Ffolliott and Clary 1975).

Total herbage production levels on the Heber watersheds are less than estimated for untreated conditions on the Beaver Creek watershed (Brown et al. 1974).

Herbage production on the Heber watersheds at a given level of tree density or depth of forest floor was approximately one-half that produced on the Beaver Creek watershed (Clary and Ffolliott 1966, Clary et al. 1968).

The depths and weights of the forest floor on the Heber watersheds are similar to those found on volcanic soils as characterized on the Beaver Creek watershed (Ffolliott et al. 1968).

The primary difference in browse frequencies observed on the Heber and Beaver Creek watersheds is the greater occurrence of ceanothus at Heber.

Summary

The physiographic, hydrologic, and biotic information that characterizes the Heber watersheds is assumed to be representative of ponderosa pine ecosystems on porous sandstone soils in north-central Arizona. Based on this information and that obtained from ponderosa pine ecosystems on soils derived from volcanic materials, the following comparisons can be made regarding products and uses of the land:

- Annual water yield measured at the flume from sandstone soils is approximately 25% of that from volcanic soils.
- Physical and chemical water qualities (suspended sediment concentrations and dissolved chemical constituents) are similar on both soil types.
- Forest densities on the sandstone soils are less than on the volcanics, and, therefore, annual growth of the ponderosa pine stands on sandstone is greater because of higher individual tree growth rates. Site index is also higher on the sandstone soils. Timber quality is similar on both areas.
- Total herbage production on the sandstone soils is less than has been estimated on the volcanics. Furthermore, herbage production on sandstone soils at a given level of tree density or depth of forest floor is less than produced on volcanic soils.

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PLANTS

Common Name	Scientific Name
Trees	
alligator juniper	*Juniperus deppeana*
Gambel oak	*Quercus gambelii*
ponderosa pine	*Pinus ponderosa*
quaking aspen	*Populus tremuloides*
Shrubs	
Fendler ceanothus	*Ceanothus fendleri*
New Mexican locust	*Robinia neomexicana*
Grasses, Grasslike Plants, and Forbs	
Arizona fescue	*Festuca arizonica*
black dropseed	*Sporobolus interruptus*
blue grama	*Bouteloua gracilis*
bottlebrush squirreltail	*Sitanion hystrix*
broom snakeweed	*Gutierrezia sarothrae*
showy goldeneye	*Viguiera multiflora*
mutton bluegrass	*Poa fendleriana*
sedge	*Carex* spp.
showy aster	*Aster commutatus*
western ragweed	*Ambrosia psilostachya*

ANIMALS

Mammals	
Abert squirrel	*Sciurus aberti*
cottontails	*Sylvilagus* spp.
elk	*Cervus canadensis*
mule deer	*Odocoileus hemionus*
Birds	
Merriam's turkey	*Meleagris gallopavo*

Ffolliott, Peter F., and Malchus B. Baker, Jr. 1977. Characteristics of Arizona ponderosa pine stands on sandstone soils. USDA For. Serv. Gen. Tech. Rep. RM-44, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

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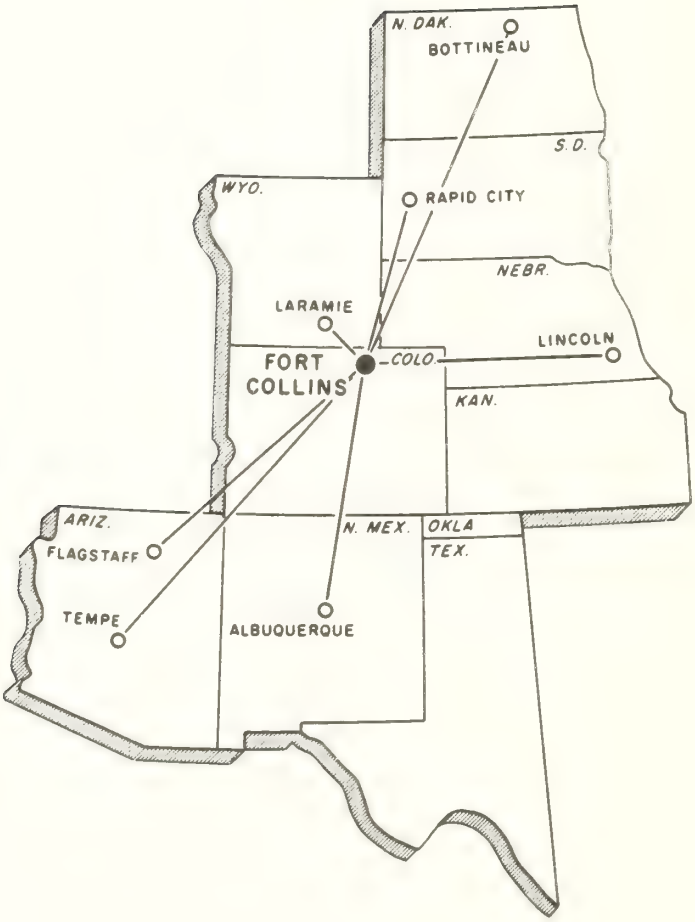
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Western Pine-Shoot Borer:
A Threat to Intensive Management of Ponderosa Pine in the Rocky Mountain Area and Southwest

USDA Forest Service
General Technical Report RM-45
November 1977



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Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture
Fort Collins, Colorado 80521

Western Pine-Shoot Borer:
A Threat to Intensive Management of Ponderosa Pine in the Rocky Mountain Area and Southwest

The western pine-shoot borer, *Eucosma sonomana* Kearfott (Lepidoptera:Olethreutidae), is attracting increased attention in the western United States as a pest of ponderosa pine, *Pinus ponderosa* Laws. The insect attacks new pine shoots, deforming leaders and reducing height growth. Stoszek (1973) described severe damage to plantations in southeastern Oregon.

We have found infestations of *E. sonomana* near Chevelon, Coconino County, Ariz.; Jemez Springs, Sandoval County, N.M.; and Pagosa Springs, Archuleta County, Colo. A more recent trapping study, still unpublished, indicates that *E. sonomana* is widely distributed throughout the entire western U.S., and we expect it will become increasingly recognized as an important pest wherever intensive forestry is practiced. The purpose of this report is to alert Rocky Mountain area and southwestern foresters to the insect, the damage it causes, and current thinking about how to minimize losses from it.

Life History, Habits and Damage[2]

E. sonomana is a small moth that has a typical moth life history — eggs, larvae (caterpillars), a pupa or resting stage, and finally the adult insect, the moth. Activity begins in early spring when newly emerged moths mate and lay eggs on fresh pine terminals at the time the shoots are elongating. The eggs hatch within a few days. The larvae enter the leaders near the terminal buds and make their way directly to the pith, where they begin mining downward. Generally there is only one insect per shoot and, particularly in young trees, only the leader is attacked. When larval development is completed, around midsummer, the larva chews an exit hole in the lower part of the shoot and moves — at least in small trees — to the ground to build a cocoon, pupate, and overwinter in the litter. Details of the pupation site, particularly in larger trees, are scant.

The effect of larval feeding on the shoot is variable, depending on the success of the larva. The extremes are instances in which (1) the larva dies soon after entering the shoot, causing little or no damage, and (2) the larva mines the shoot so completely that the shoot dies. The damage is often somewhere between these extremes, with the

[2]*Some of the material in this section is taken from a paper entitled "Biology and control of the western pine shoot borer" presented by S. C. Cade, T. W. Koerber, and K. J. Stoszek at the annual meeting of the Entomological Society of America, Honolulu, November 28-December 2, 1976.*

larva successfully completing its development and the shoot continuing to live but being stunted. This leads to the characteristic "shaving brush" kind of leader shown in figure 1. The shoot and needles are shortened and the needle bundles are more closely spaced than normal, giving the foliage a typically dense appearance. There is usually no needle fading, nor — in ponderosa pine — any tendency of the leader to droop. This contrasts with Grant's (1958) report on *E. sonomana* in lodgepole pine, *P. contorta* Dougl., in which infested leaders are said to droop. Often the leader is not only stunted, but is also overtopped by one of the laterals. If the lateral assumes dominance, a crook or a fork results.

For 3 years, starting in 1974, we looked closely at examples of damage in 20 young trees growing near the Turkey Springs Guard Station, some 7 miles (11.3 km) northwest of Pagosa Springs, Colo., at an elevation of about 7,600 feet (2,316 m). Our main objective was to get a general picture of damage characteristics as evidenced by (1) incidence of annual attacks on individual trees, (2) effect of attack on the leader, and (3) leader replacement by uninfested laterals. The stand at Turkey Springs is pure ponderosa pine with a scattered overstory of large trees, diameter around 24 inches (61 cm) at breast height, and an understory of dense natural regeneration about 20 years old, and about 8 feet (2.4 m) tall, growing in clumps (fig. 2). We examined these young trees and chose 20 with infested terminals. We measured tree height to base of the 1974 growth, and length of the infested leaders and longest 1974 laterals. Observa-



Figure 1.—Growth of ponderosa pine leader on left has been reduced due to infestation by western pine-shoot borer.



Figure 2.—Ponderosa pine stand at Pagosa Springs, Colorado. Dense natural regeneration is infested with western pine-shoot borer.

tions were made July 16, 1974, July 24, 1975, and October 18, 1976, all after the current year's infestation had taken place.

Figure 3 shows the 3-year infestation pattern for the 20 trees. Although the pattern of annual attacks may not be well represented by such a small sample, 5 of the 20 trees infested in 1974 were hit again in 1975, and 11 were attacked in 1976. This characteristic frequent reinfestation was readily visible throughout the area. We found it impossible at the Pagosa Springs site to locate trees that had escaped infestation for more than 2 successive years that could serve as checks for height growth.

Effect of attack on the leaders, and leader replacement by uninfested laterals, are also illustrated in figure 3. Of the 20 leaders infested in 1974, 11 were outgrown the same year, and by 1976 the original (infested) leader retained dominance in only four instances. Meanwhile additional dominance shifts continued to occur.

The main long-term result of this kind of situation is reduced height growth. Depending on management objectives this may or may not be important; however, under intensive management rapid height growth is generally considered desirable. Also estimates of site quality determined by calculating age-height relationships of dominant trees will be reduced in stands having persistent *Eucosma* infestation.

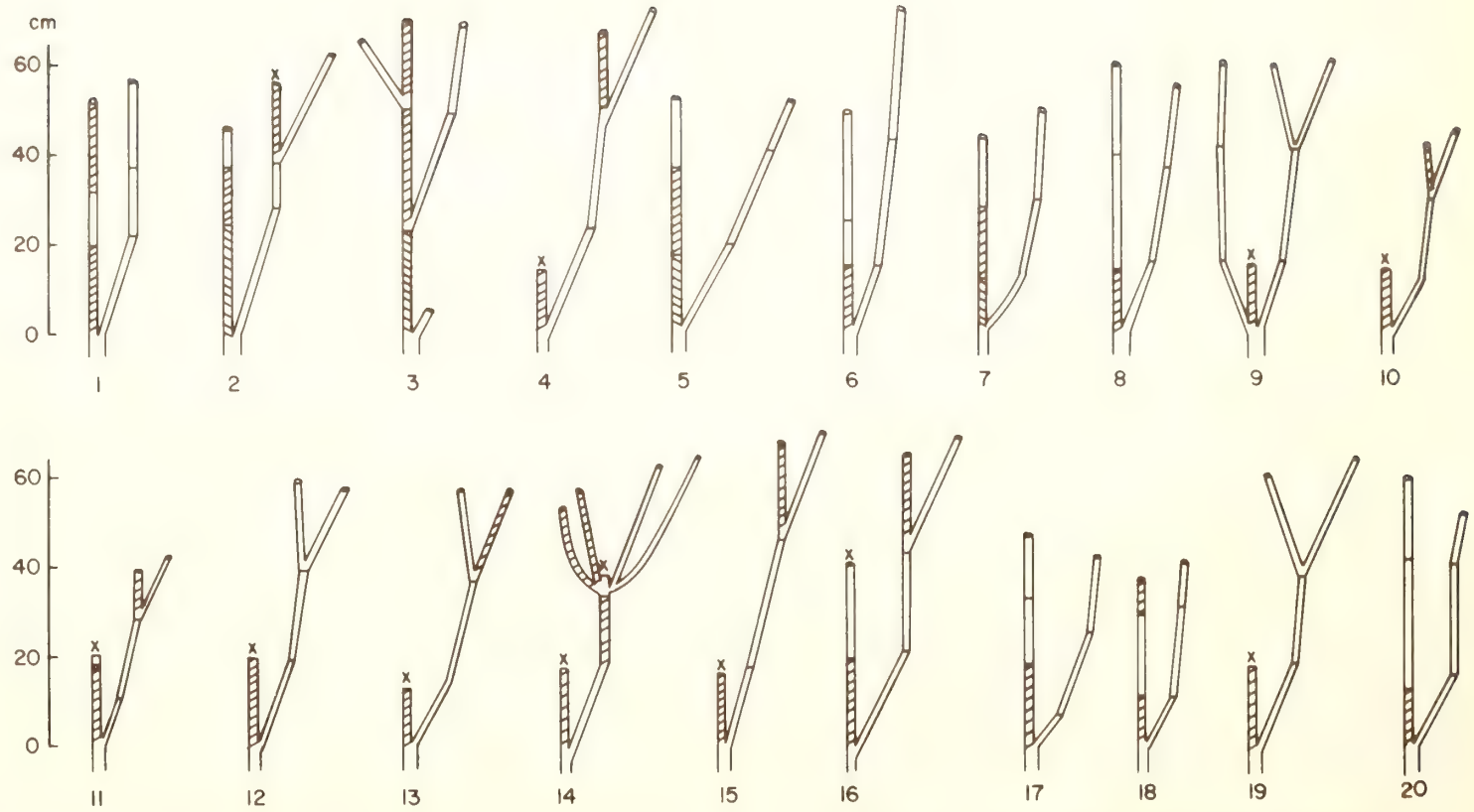


Figure 3.—Leaders and longest laterals of 20 typical infested ponderosa pine saplings at Pagosa Springs, Colorado, 1974-1976 growth. Infested shoots are shaded; dead leaders are marked with X.

Identification of Damage

In the Southwest, the long-term effects of damage caused by the shoot borer—crooks, forks, and multiple leaders—can be confused with those caused by the closely related southwestern pine tip moth, *Rhyacionia neomexicana* (Dyar). However, on close inspection they are not so hard to separate, particularly after larval feeding is completed. The tip moth mines out most of the xylem and phloem within the shoot (Jennings 1975), which then dries and eventually breaks off. In tip moth feeding the bud is almost always destroyed, and a new leader develops from one of the existing laterals. Larvae of the shoot borer, on the other hand, mine only in the pith; the leader remains green for at least another year (even if the bud dies), and the leader sometimes maintains dominance. Figure 4 illustrates the interior of infested and uninfested shoots; figure 4b shows the tightly-packed, dark brown frass left by a successful shoot borer larva. Note that the shoot borer feeding damage is confined to the pith region; the xylem and phloem are not involved as they are in the case of tip moth. Less successful larvae leave less frass, but the frass is always confined to the pith. When an infested shoot continues to live the frass in the pith area remains, providing a long-term indicator of the insects' activity. With time, however, the frass becomes increasingly suffused with resin and is often hard to distinguish from healthy pith. The following key summarizes ways to separate active or recent shoot borer activity from that of the tip moth in young trees.

	Shoot Borer *(Eucosma)*	**Tip Moth** *(Rhyacionia)*
Location of Damage	Usually terminal only; laterals rarely	Terminal and laterals
External Symptoms		
Shoot	Thickened; remains sturdy and erect	Not thickened; dries and becomes brittle, often breaks off
Needles	"Shaving-brush" appearance; shortened, usually remain green	Greatly shortened; rapidly turn yellow, then brown
Internal Symptoms	Pith mined, tightly packed with frass; xylem and phloem not damaged	Pith generally intact, xylem and phloem destroyed; large amounts of coarse, loosely packed frass in shoot

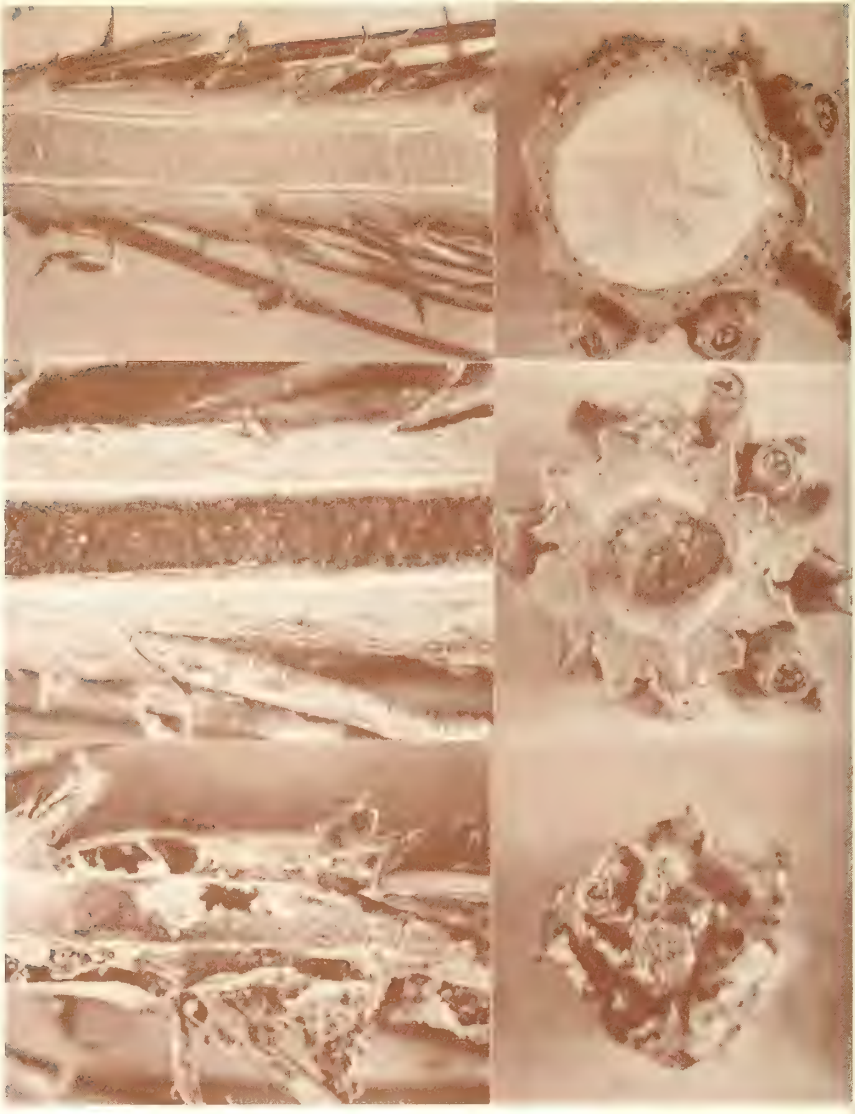


Figure 4.—Longitudinal and cross sections of (top) normal ponderosa pine leader and leaders infested with (middle) western pine-shoot borer or (lower) southwestern pine tip moth.

Shoot borers and tip moths can both infest the same shoot. We noted this particularly at the Arizona site, where some young, open-growing trees in plantations heavily infested with tip moths were also colonized by *Eucosma*.

Possibilities for Minimizing Shoot Borer Impact

Currently, no practical suppression measures for the shoot borer are known. Considering the shoot borer's life history and habits, primarily the fact that it is deep in tree tissue or in a cocoon much of its life, ordinary control methods are not effective. Recent efforts with systemic insecticides have not been encouraging. However, research to develop methods is underway, and some approaches remain to be tried.

Thinning would not appear to be helpful; in fact, Grant (1958) felt that open-grown stands were most susceptible to *E. sonomana* infesting lodgepole pine (*P. contorta* Engl.) in British Columbia. We have no information about incidence of attack as related to stand density in southwestern ponderosa pine, but close spacing certainly does not seem to be advantageous. Clipping and destroying infested shoots might be a possibility in some instances, but these shoots are very difficult to distinguish during the short period they are occupied by the larvae. Moth invasion from adjacent untreated areas could be a problem with this approach.

Developing stands having a mixture of species, e.g., ponderosa pine and Douglas-fir, might be useful; however, planting mixed stands is not generally done and would represent a radical departure from standard procedures.

Two other unconventional approaches may offer promise. The relatively low population densities characteristic of *E. sonomana* (i.e., one or only a few insects per infested tree) make it a possible candidate for suppression using attractants. Male moths can be lured to sticky traps baited with virgin females, and also to certain synthetic attractant pheromones. Work is currently underway on the West Coast to test several of these synthetic materials for suppression purposes.

In view of the insect's habit of overwintering in, or in the vicinity of, the litter, it has been suggested that controlled burning might give some measure of suppression. Controlled burning has not been tried, and may have some serious drawbacks. For example, would a useful percentage of overwintering insects be killed, and what damage would the trees sustain from the treatment? Also, possible invasions from adjacent untreated areas might pose problems.

For the time being it would seem prudent for managers in the Rocky Mountains and the Southwest — if they have alternatives — to concentrate silvicultural efforts such as planting and thinning in locations other than where *E. sonomana* is a known pest. There may be extensive areas where the species does not exist in densities high enough to cause problems. More surveys to determine its occurrence and impact are needed.

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The western pine-shoot borer damages terminals of young ponderosa pines, causing deformity and reduced height growth. The insect occurs throughout the western United States, including locations in the Rocky Mountain area and the Southwest. There are currently no satisfactory control measures.

The southwestern pine tip moth produces somewhat similar damage symptoms over much of the same area, and comparative methods are presented for separating the two kinds of symptoms.

Keywords: Olethreutidae, *Eucosma sonomana, Rhyacionia neomexicana, Pinus ponderosa.*

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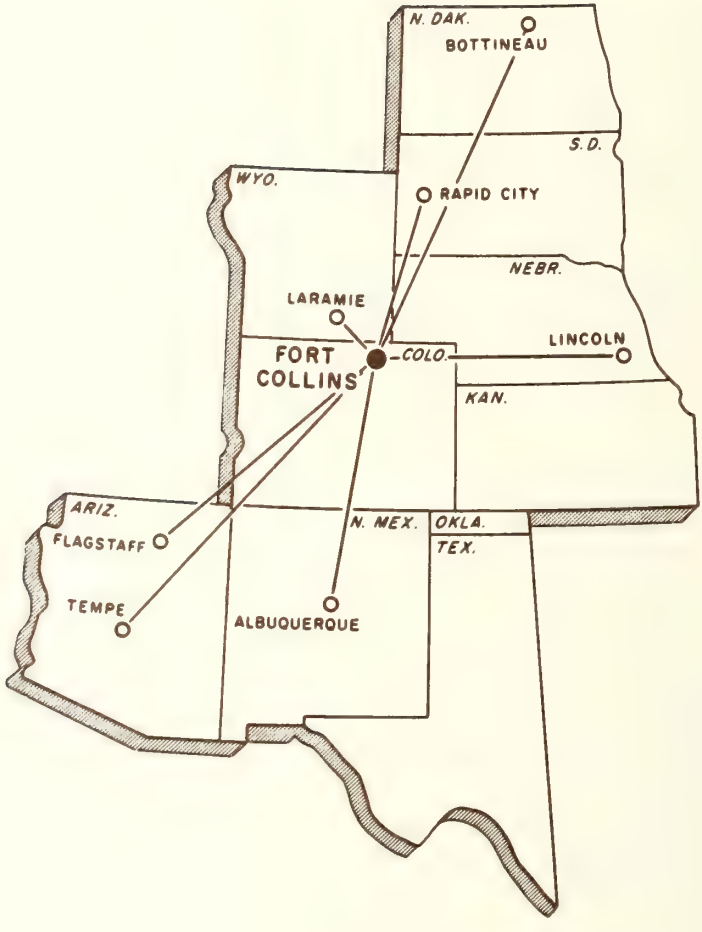
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The Front Range Pine Type

A 40-Year Photographic Record of Plant Recovery on an Abused Watershed

Howard L. Gary and Pat O. Currie



1937



1977

Rocky Mountain Forest and
Range Experiment Station
Forest Service
U. S. Department of Agriculture
Fort Collins, Colorado 80521

USDA Forest Service
General Technical Report RM-46
November 1977

Abstract

Photographic comparisons revealed the relative success of plant recovery was mainly from tree planting with ponderosa pine in the early 1930's by the Civilian Conservation Corps. Shrubby and herbaceous ground cover showed only slight improvement. Potential for sheet and gully erosion also remained about the same, although excessive erosion has not occurred during the last 40 years.

SDA Forest Service
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November 1977

The Front Range Pine Type

A 40-Year Photographic Record of Plant Recovery on an Abused Watershed

Howard L. Gary, Principal Hydrologist

and

Pat O. Currie, Principal Range Scientist

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The Front Range Pine Type

A 40-Year Photographic Record of Plant Recovery on an Abused Watershed

Howard L. Gary and Pat O. Currie

The Front Range of the Colorado Rockies, particularly that portion west of Colorado Springs, has a long history of use and abuse. Exploitation began about the time the United States acquired ownership of the region in 1803 as part of the Louisiana Purchase. The military expeditions of Lieutenants Zebulon M. Pike in 1806 and John C. Fremont in 1842 further opened the country to settlement. The discovery of placer gold and rich gold and silver veins in the mountains west of South Park in the 1850's marked the beginning of rapid settlement, and the large influx of people created a heavy demand for various lumber and livestock products. The discovery of gold at Cripple Creek in 1890-91 marked yet another period of rapid settlement and placed even greater demands on the timber and range resources. As the villages grew into towns, the readily accessible ponderosa pine lands were cut over repeatedly. They were also heavily grazed, and both resources were substantially diminished by 1900.

Extensive timber removal and ground cover reduction by overgrazing had an obvious impact upon the watersheds of the region. Much topsoil is gone from the most accessible portions of the ponderosa pine forests along the Front Range. Most meadows and hillsides are also lined with gullies, and exposed roots of old tree stumps are stark testimony of past erosion. By the early 1930's, demand for high quality water for irrigation and domestic use by the foothills and plains cities led to a general awareness of the importance of watershed rehabilitation and the need to reestablish vegetation cover to reduce sediment loads entering the South Platte and Arkansas river systems. Vegetation cover was also recognized for its esthetic value and maintenance of wildlife populations.

The U.S. Forest Service first assessed soil loss in the region in the mid-1930's to determine the approximate area of eroding lands and remedial actions needed for better watershed management[2]. Part of the overall study included a photographic survey of the existing plant cover on selected watersheds[3]. This paper uses one photographic record to examine the recovery and reestablishment of plant cover after 40 years of protection from domestic livestock grazing and after tree planting on a typical abused watershed in the Front Range pine type.

Study Area

The watershed selected for study was Trail Creek in the Pike-San Isabel National Forest about 3.2 km (2 miles) southwest of the community of Westcreek and about 48 km (30 miles) northwest of Colorado Springs, Colo. (fig. 1). The watershed has an average elevation of about 2,288 m (7,500 feet). The watershed has received only light recreational use during the past 40 years. Ponderosa pine (*Pinus ponderosa* Laws.) is found on the drier sites, and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and quaking aspen (*Populus tremuloides* Michx.) on the wetter sites. The sparse woody understory is mainly bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.), true mountainmahogany (*Cercocarpus montanus* Raf.), rose (*Rosa* spp. L.,) currant (*Ribes* spp. L.), cinquefoil (*Potentilla* spp. L.), and yucca (*Yucca* spp. L.). The principal forbs are fringed sagebrush (*Artemisia frigida* Willd.), other *Artemisia* spp., Rocky Mountain pussytoes (*Antennaria parvifolia* Nutt.) and milkvetch (*Astragalus*

[2]*Connaughton, Charles A. 1939. Erosion on the National Forests of Colorado, eastern Wyoming, and western South Dakota. 68 p. [Unpublished report on file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.]*

[3]*Johnson, W. M. 1940. Establishment report of range recovery study Pike and Cochetopa National Forests. 13 p. [Unpublished report on file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.]*

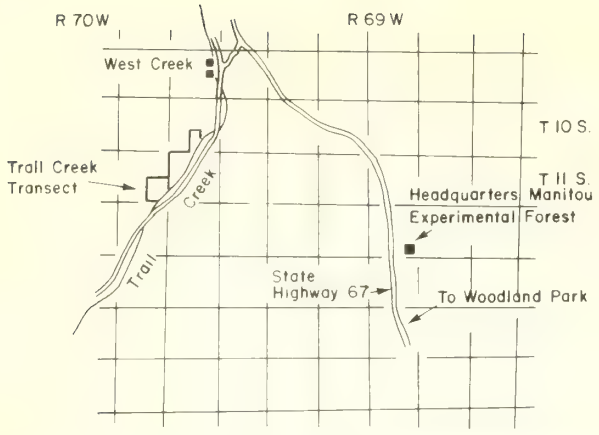


Figure 1.—Location of the Trail Creek photographic survey transect.

spp. L.). Scattered to locally abundant grasses are mountain muhly (*Muhlenbergia montana* (Nutt.)), Arizona fescue (*Festuca arizonica* Vasey), blue grama (*Bouteloua gracilis* (H.B.K. Lag.), little bluestem (*Andropogon scoparius* Michx.), prairie junegrass (*Koeleria cristata* (L.) Pers.), sleepy grass (*Stipa robusta* (Vasey) Scribn.), bromegrass (*Bromus* spp. L.), Kentucky bluegrass (*Poa pratensis* L.), and sedges (Carex spp. L.).

The soil, derived from the underlying Pikes Peak granite, is relatively infertile and coarse textured with little profile development. The unconsolidated soil mantle ranges up to 9.2 m (30 feet) deep. The exposure lies generally north and east with steep rolling slopes. Long-term average annual precipitation for a similar elevation at the Manitou Experimental Forest 9.7 km (6 miles) east of the study area was 404 mm (15.9 inches). About two-thirds of the annual precipitation falls during the growing season, from April through September. Winter snows generally melt within a few days on the south exposures, but may persist on protected north exposures.

Slash fires during the early logging operations were reported to have destroyed many of the seedling pines and much understory vegetation. To replace this loss, ponderosa pine and some Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) seedlings were planted over much of the area in the early 1930's by the Civilian Conservation Corps. The Trail Creek watershed has also been closed to all domestic grazing since 1934. Resident deer and other big game are scarce.

Methods

In 1936, a transect about 5.6 km (3.5 miles) long was established to sample representative conditions over the lower half of the Trail Creek watershed (fig. 2.). The transect was laid out in a zigzag fashion along section and quarter-section land survey lines. At approximately 100-m (5-chain) intervals, a 1.27-cm (½-inch) iron pipe was driven into the ground and given an identification number to help locate the transect. Eleven randomly selected locations were designated as camera points in the initial watershed evaluations. Rock monuments were erected near the camera

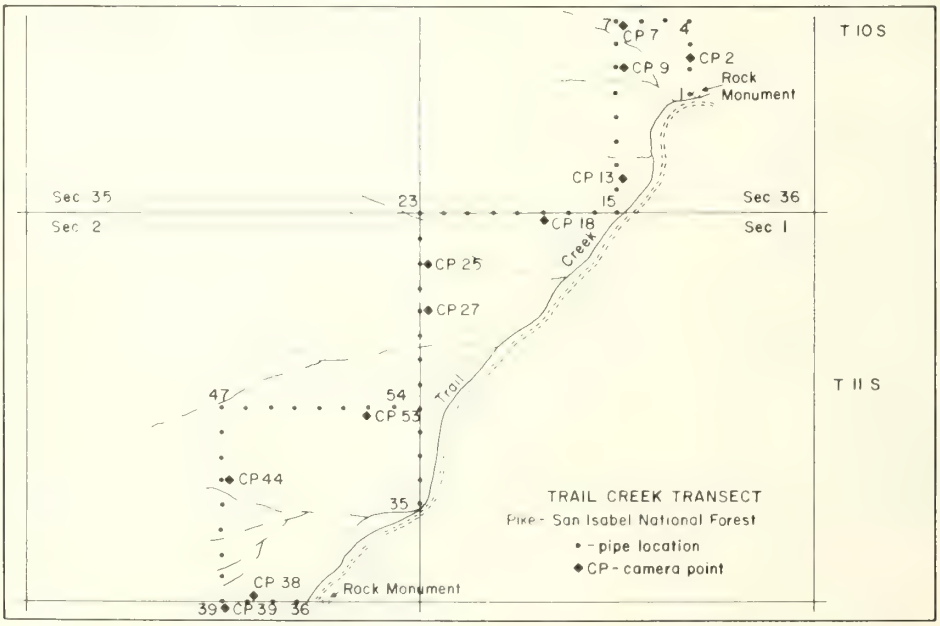


Figure 2.—Camera point locations along the Trail Creek transect.

points to help locate the points in the future. Most of the pipes were found in the 1977 survey. Barring extensive vandalism, it should be possible to relocate all camera points in the distant future.

In August 1937, photographs were made with a 5x7 view camera at the 11 camera points, with 20 photo directions, to illustrate a wide range of watershed conditions. The negatives for the 1937 and 1977 photographs were deposited in the USDA, Forest Service photographic file in Washington, D.C. In the August 1977 survey, all camera points were located, and the associated views rephotographed with a similar 5x7 view camera. In some instances a few small trees and branches were removed from the camera points to obtain the same approximate view photographed in 1937. Care was taken not to destroy or unnecessarily damage the existing vegetation. Some photographs taken in 1977 appear slightly different from the 1937 photos due to camera placement, tree growth, new trees, shadows and small differences in film. Sixteen photo directions are presented in this paper. Identification numbers of the photos used in this paper correspond to the identification used in 1937 (fig. 2).

Results and Discussion

After 40 years of recovery and soil stabilization, a panoramic view of the central portion of the Trail Creek watershed as it appeared in 1937 and 1977 is best illustrated from camera point 9 west and northwest (fig. 3). Most of the stumps visible in the 1937 photographs were fire scarred. Their spacing



Figure 3.—Panoramic view from camera point No. 9. Sheep Nose is in the left background.

indicates the original pine forest was rather open. Topography is typical of the entire watershed and shows the easy accessibility for early logging and downhill skidding using teams of horses. Ground cover in 1937 was mainly bearberry, mountain muhly, and blue grama. The tree cover in 1977 masks the topography but shows the land has capacity for natural regeneration and low grade timber growth, if given sufficient time. A high density mat of bearberry dominates the lower left foreground of the 1977 photos and shows local stabilization of the site.

Widely scattered mats of bearberry were present in most of the early photographs, and most mats were still present and had expanded by 1977 (camera point 38, fig. 4). Bearberry appears to be a long-lived plant when left undisturbed, is tolerant of partial shade, and provides good local soil stabilization. True mountainmahogany, a desirable browse plant, is also now plentiful in the same area. Yucca and some of the grasses appear to have decreased because of partial shade provided by the surrounding trees.

It is of interest to note that areas of bare ground visible in 1937 were generally bare in 1977 (camera point 2, fig. 5). The lack of cover attests to the harshness and shallow soils of many sites which



1937

360053



1977

525085

Figure 4.—Bearberry cover at camera point No. 38.



1937

389305



1977

525078

Figure 5.—Confluence of two drainages at camera point No. 2.

inhibit natural plant establishment. Also, as shown in camera point 7 west (fig. 6), the steep bare slopes which today one might expect to have eroded because of lack of vegetation have changed little in 40 years. Close examination reveals that some sheet erosion has occurred, but the steep slope has not been deeply incised with new gullies. The steep slope was somewhat more rounded in 1977 but appears relatively stable for the average local climate. It appears that regeneration of trees and resultant needle drop have helped stabilize the topography.

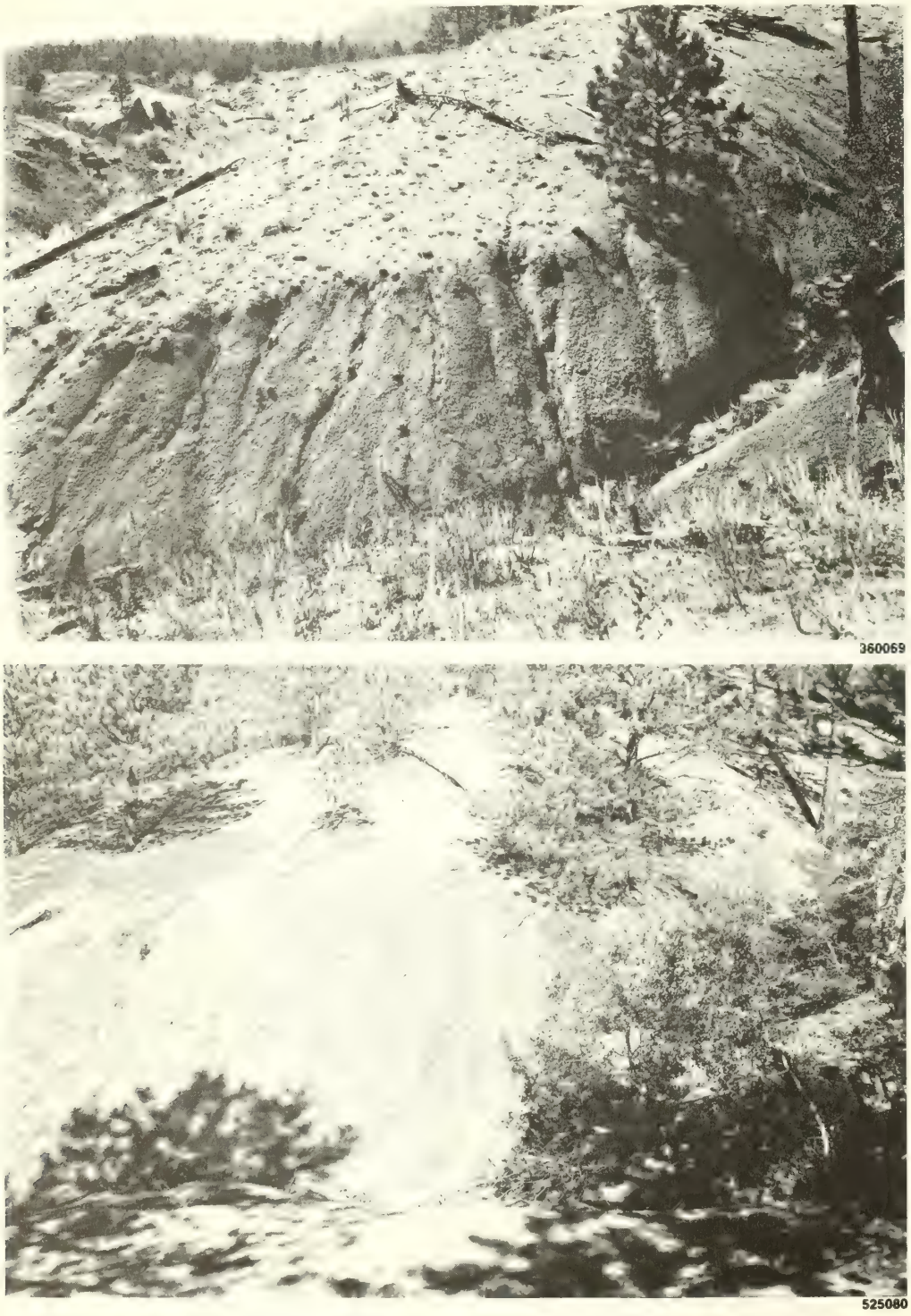


Figure 6.—Steep slope west of camera point No. 7.

In the same area, at camera point 7 north (fig. 7) tree growth was also slow on the bare south facing slope planted to ponderosa pine. Estimated tree heights averaged 4.2 m (13.8 feet), and measured diameters averaged 11.7 cm (4.6 inches). This slow growth appears to be a reflection of the harsh dry microclimate of south slopes. This harshness also limits understory plant growth, and little vegetation was present in 1977. A protective cover of pine needles was forming, however, and in time will add further protection to the site. All photos at camera point 7 (figs. 6 and 7) illustrate that without disturbance these areas are rather stable even though vegetation recovery is slow. Based on the 40-year time span, the amount of cover vegetation or dead organic matter, will be limited for many more decades and will be critical to the preservation of the soil resource.



1937

360068



1977

525079

Figure 7.—Reforested south facing slope at camera point No. 7.

Examples of artificial and natural reforestation on two north facing slopes near the center of the watershed are shown in camera points 9 south and 13 south (figs. 8 and 9). The site shown in figure 8 was planted to ponderosa pine in the early 1930's, and growth of the surviving trees was rated good for the site. The understory vegetation consisted mainly of bearberry and mountain muhly which changed little in 40 years. The apparently more moist site shown in figure 9 was not planted to trees. It may have been thought adequately stocked and that aspen would dominate and stabilize the site, or that protection from grazing alone would allow reforestation to occur. At any rate, the stage of natural reforestation with conifers on this site appears many years younger than that observed on the planted site shown in figure 8. In time, the Douglas-fir also present on the site shown in figure 9 will outgrow any trees now on the planted site.

1937



360066

1977



525083

Figure 8.—View south of camera point No. 9.

Minor soil sloughing is still occurring near the toe of the slope shown in figure 9, but the bankside present 40 years ago appears to be stabilizing. Based on comparison of the two sites shown in figures 8 and 9, it is clear that early successful tree planting on depleted sites will result in earlier watershed stabilization and earlier recovery of wood production. Apparently because of higher soil moisture for the site shown in figure 9, there was a greater diversity of ground cover than at any other photo station. The principal plants were mountain muhly, little bluestem, blue grama, prairie junegrass, *Stipa* spp., *Bromus* spp., Kentucky bluegrass, *Carex* spp., fringed sagebrush, and other *Artemisia* spp.



Figure 9.—North facing slope at camera point No. 13.

The eastern boundary of the Trail Creek watershed was visible from camera point 9 east (fig. 10). The mountain range on the skyline was not heavily logged during the late 1800's because of low quality trees and steep terrain. The foreground area was successfully planted to ponderosa pine in the early 1930's. As observed in most other areas of the watershed, ground cover has changed little as a result of protection from grazing. In the immediate foreground of figure 10, it appears that density of blue grama and *Yucca* spp. has increased slightly and that bearberry has declined. Observations on the ground substantiate this photographic impression.

1937



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1977



525082

Figure 10.—View east of camera point No. 9.

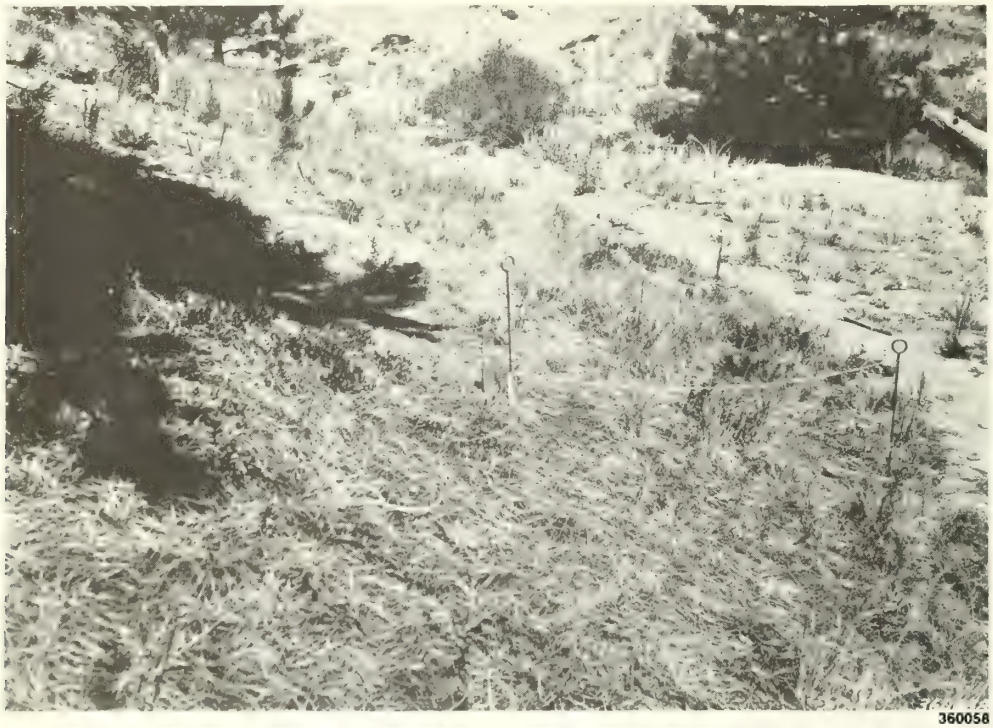
A panoramic view of plant community change in an open ponderosa pine stand is illustrated by the west-southwest views from camera point 18 (fig. 11). The density of the herbaceous ground cover shown in the foreground increased substantially in the drainage bottom, but only slightly on the slopes after 40 years of protection. The watercourse seems to have stabilized with the increased vegetation. The main grasses today are little bluestem, blue grama and mountain muhly. Bearberry density appears to have increased more than the density of the palatable grasses listed above. True mountainmahogany plants are in greater abundance today than in 1937. Some specific plants are in the same locations, suggesting long-lived plants and some capability to recover from severe overbrowsing. The new trees present in figure 11 in 1977 were the result of natural regeneration, and, in time, true mountainmahogany and ponderosa pine will likely occupy the grassy foreground.



Figure 11.—Panoramic view west from camera point No. 18.

Established ponderosa pine trees in the Front Range increase shade and litter production (needlecast) and are generally detrimental to the growth and/or reestablishment of a herbaceous understory. A dense litter cover does, however, protect the soil mantle, and will generally maintain itself for some period beyond the life of the trees. An example of a heavy litter cover was present at camera point 25 (fig. 12) where encroachment by herbaceous vegetation has changed little in 40 years. The small draw also shows little evidence of sedimentation or erosion.

1937



360058

1977



525084

Figure 12.—Litter mat under ponderosa pine at camera point No. 25.

No widespread accelerated erosion was found in any of the arroyos within the watershed. At camera point 13 west (fig. 13), the photograph for 1937 shows a definite channel and general evidence that water periodically flowed down the channel. The channel is well defined today, but there was no apparent evidence of recent water flows. The lack of any recent flows may simply reflect storm size and frequency of occurrence. The lack of erosion may also reflect recent stability of the site. The average diameter of trees in the foreground is 20.6 cm (8.1 inches) and estimated average height is 6.6 m (21.5 feet).

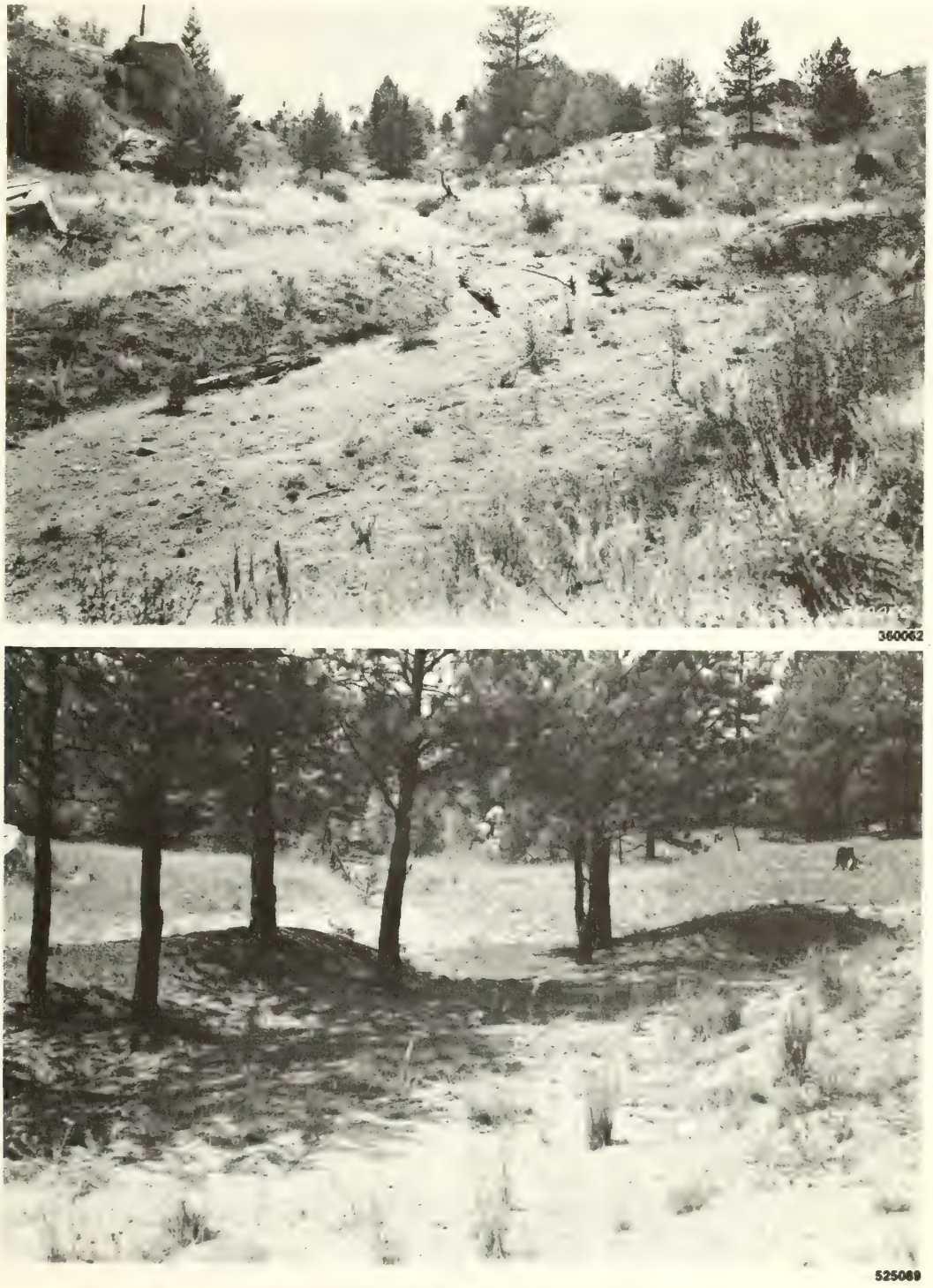


Figure 13.—Drainage west of camera point No. 13.

Two views at the upper reaches of the watershed are shown from camera point 39 north and west (figs. 14 and 15). Most of this area was replanted to ponderosa pine in the early 1930's. The area shown in fig. 15 was also planted at the same time. The presence of aspen on both sites in 1937 provided evidence of good sites for the reforestation efforts. Estimated average tree height in both areas is 3.6 m (11.9 feet) and measured diameter averages 8.7 cm (3.4 inches). The herbaceous ground cover that was present in 1937 appears to be on the decline.

1937



360051

1977



525087

Figure 14.—View north of camera point No. 39. Sheep Nose is in the left background.



1937

360052



1977

525086

Figure 15.—View west of camera point No. 39.

A south facing aspect (camera point 44 south) in the same general area as shown in figures 14 and 15 was also planted to both ponderosa pine and Rocky Mountain juniper (fig. 16). Stumps present over the general region shown in figures 14, 15, and 16 further illustrate that usable timber was produced in the past. Successful reestablishment of ponderosa pine and juniper over the area gives some assurance the area will again produce usable wood products and shrubby ground cover.

1937



360055

1977



525093

Figure 16.—View south of camera point No. 44. Signal Butte is in right background and near upper reaches of the watershed.

Summary and Conclusions

During a 40-year period since livestock grazing was removed from the Trail Creek watershed, there has been little further deterioration of the soil mantle, fair establishment of tree and shrubby ground cover on most sites, and some improvement of litter cover. The success of the vegetative recovery was mainly from tree planting efforts in the early 1930's by the Civilian Conservation Corps. Natural restocking of ponderosa pine appeared slower than planting and was more dependent upon interacting factors such as abundance of seed trees, slope exposure, existing ground cover, soil conditions, appropriate seed bed, and weather. Shrubby and herbaceous plant cover changes were generally less pronounced except for bearberry which increased considerably throughout the watershed during the last 40 years. Today, many individual bearberry plants range up to 3 feet in diameter. Some localized stands have formed a dense ground mat that prevents further erosion and contributes to wildlife habitat.

In general, the photos showed some reestablishment of the more palatable bunchgrasses, such as mountain muhly and Arizona fescue. There was also a decline of grasses in some areas due to litter accumulation and increased shading by the young trees. Most of the areas were originally open forests which would have allowed some grass establishment, but reestablishment of grass may take considerably longer than 40 years with the existing site conditions.

Watershed rehabilitation is a slow process in the Front Range pine type, particularly because of low annual rainfall, low soil fertility and highly erosive soils, especially those derived from granites. In abused watershed areas such as Trail Creek, it appears that we must help nature through planting efforts in order to more rapidly regain the potential productivity of forests and rangelands. Today, abused watersheds such as Trail Creek, remind us that good land use planning and wise use of forest lands are necessary to protect the soil, vegetation, and water resources. Good stewardship of the land will also help maintain downstream reservoir storage and reduce sedimentation of flood control structures.

Gary, Howard L. and Pat O. Currie. 1977. The Front Range pine type - A 40-year photographic record of plant recovery on an abused watershed. USDA For. Serv. Gen. Tech. Rep. RM-46, 17p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Photographic comparisons revealed the relative success of plant recovery was mainly from tree planting with ponderosa pine in the early 1930's by the Civilian Conservation Corps. Shrubby and herbaceous ground cover showed only slight improvement. Potential for sheet and gully erosion also remained about the same, although excessive erosion has not occurred during the last 40 years.

Keywords: Watershed management, gully erosion, livestock grazing.

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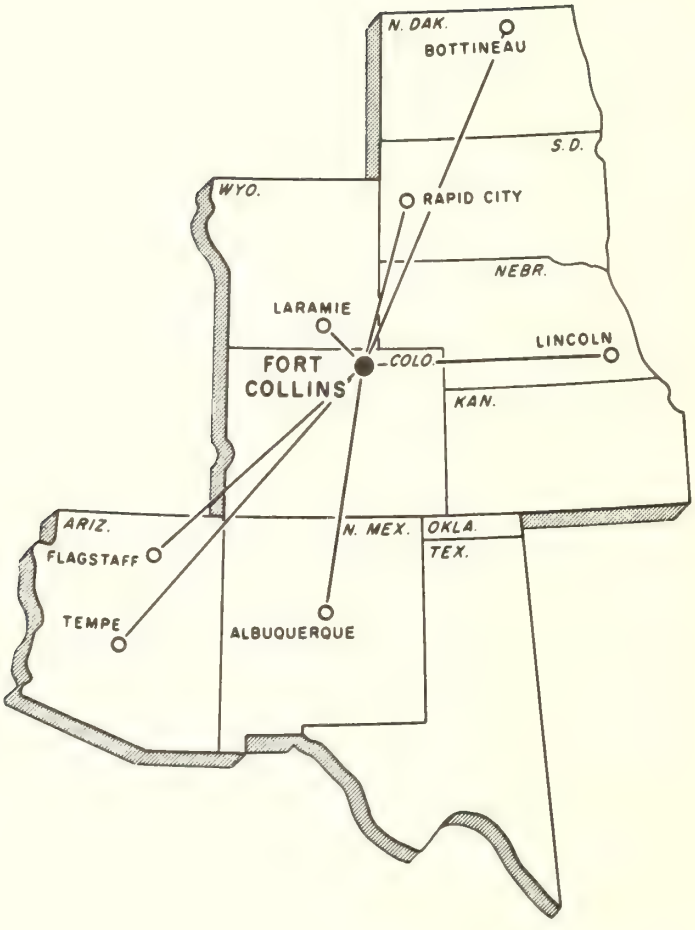
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Managing Pinyon-Juniper Ranges for Wildlife

Henry L. Short and Clay Y. McCulloch



APR 19 1978

USDA Forest Service
General Technical Report RM-47
November 1977

Rocky Mountain Forest and
Range Experiment Station
Forest Service
U. S. Department of Agriculture
Fort Collins, Colorado 80521

Abstract

Reviews, in a general way, the distribution and composition of pinyon-juniper woodlands in the western United States and the animal communities occupying the woodlands. Describes general procedures for managing the woodlands in a manner advantageous to wildlife.

USDA Forest Service
General Technical Report RM-47

November 1977

Managing Pinyon-Juniper Ranges for Wildlife

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[2]*Central headquarters located at Fort Collins in cooperation with Colorado State University. Research summarized here was conducted at the Station's Research Work Unit located at Tempe in cooperation with Arizona State University.*

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Managing Pinyon-Juniper Ranges for Wildlife

Henry L. Short and Clay Y. McCulloch

Introduction

The pinyon-juniper woodland type occurs throughout much of the southern and central interior portions of western North America. These discontinuous woodlands are scattered throughout a large area that varies in topography, precipitation, and climatic severity. The pinyon-juniper woodland type is potentially useful to the game manager, frustrating to the stockman, of some potential economic usefulness to citizens of the Southwest, and a visual relief to the western visitor anxious for a view of a tree.

Extent and Composition of Pinyon-Juniper Woodlands

Trees of the genus *Juniperus* grow throughout North America, although the pinyon-juniper association generally occurs from central Mexico through west Texas, into the Four Corner States of New Mexico, Colorado, Arizona, and Utah, and west through Nevada into eastern and central California. The different pinyons and junipers important to this woodland type are described in detail by Tueller and Clark (1975).

The pinyon (*Pinus edulis* Engelm.) is a relatively small, bushy, needle-leaved evergreen tree, 15-35 feet tall, which occurs either in pure stands or in association with junipers on dry, rocky foothills, mesas, plateaus, and lower mountain slopes between the desert shrub, desert grassland or chaparral type, and coniferous forests. The pinyon occurs frequently in the Four Corner States (fig. 1) in a zone between 5,000 and 7,000 feet. Pinyons are widespread, abundant, and highly drought resistant, growing in a zone that frequently receives only 12-18 inches of rain a year (Little 1950). Summers are very dry in the northern and western portion of the range but become increasingly moist along a southeasterly gradient.

Single leaf pinyon (*Pinus monophylla* Torr. and Frem.) is common throughout the lower elevations (2,000 to 7,000 feet) of the isolated mountain ranges of the Great Basin (fig. 1), where it occurs as pure stands or in association with junipers on arid, gravelly slopes and mesas. This tree occurs to the north and west of the pinyon, and its range extends to eastern and central California and northern Baja California (Critchfield and Little 1966).

The Mexican pinyon (*Pinus cembroides* Zucc.) is widespread at low elevations in the mountains bordering the arid plateau of northern Mexico, and ranges from west Texas to central Mexico (Critchfield and Little 1966). The approximate distribution of the Mexican pinyon within the United States is indicated by the shaded pattern in figure 1.

At least four major species of junipers are associated with these three pinyons in the western United States. Junipers are small to medium-sized, scale-leaved evergreen trees up to about 40 feet tall. In addition to occurring in pinyon-juniper woodlands, scattered alligator junipers (*Juniperus*



Figure 1. Approximate ranges of three species of pinyon pines in the United States. Pice=*Pinus cembroides*; Pied =*P. edulis*; and Pimo=*P. monophylla*.



Pinyon-juniper stands vary in appearance from dense with little herbaceous understory (left) to open with good grass cover (right).

deppeana Steud.) grow on hillsides and mountains in the chaparral and oak woodland types and within lower portions of ponderosa pine forests at about 4,500 to 8,000 feet. Their approximate range in the mountainous terrain of the southwestern United States is indicated by the shaded pattern in figure 2.

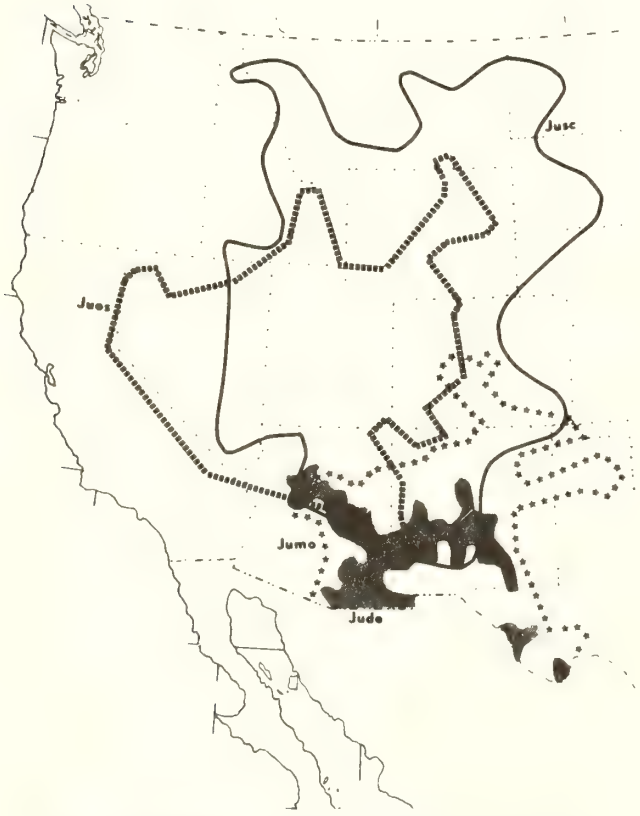


Figure 2. Approximate ranges of four important species of juniper that occur with pinyon pines in the United States. Jude=*Juniperus deppeana*; Jusc=*J. scopulorum*; Jumo=*J. monosperma*; and Juos=*J. osteosperma*.

Rocky Mountain junipers (*J. scopulorum* Sarg.) occur as scattered trees in pinyon-juniper woodlands and along the lower edges of ponderosa pine forests at about 5,000- to 9,000-foot elevations. They grow in mountains and canyons in a widely scattered distributional pattern throughout the Rocky Mountain region (fig. 2).

One-seed junipers (*J. monosperma* (Engelm.) Sarg.) are common throughout suitable range in New Mexico, and are found in east central and southeastern Arizona, south central Colorado, and west Texas (fig. 2). The tree is common and widespread on plains, plateaus, and foothills of pinyon-juniper woodlands, and occurs in pure open stands in the upper portion of desert and desert grassland habitats at 3,000- to 7,000-foot elevations.

Utah juniper (*J. osteosperma* (Torr.) Little) is the most common juniper in Arizona where it may occur as an associate within the chaparral or as an invader in short grass prairies and desert grasslands. This tree is abundant on semiarid plains, hills, and mountains, and may occur either in pure stands or in conjunction with pinyon. The tree is found at 3,000- to 7,500- foot elevations throughout much of the Great Basin (fig. 2). Other juniper species, not listed on figure 2, such as western juniper (*J. occidentalis* Hook.) and California juniper (*J. californica* Carr.), may also be locally important in pinyon-juniper woodlands (Lanner 1975).

Precipitation during the growing season may affect the distribution of different trees in the woodland type (Woodin and Lindsey 1954). *Pinus cembroides* may be more adapted to dry conditions than are *J. monosperma*, *P. edulis*, or *J. scopulorum*. East of the Continental Divide, the different associations of pinyon-juniper trees are correlated with the start of summer rains. *Pinus edulis* grows in association with *J. monosperma* in areas of New Mexico receiving the first heavy rains in July and August, and with *J. scopulorum* in south central Colorado where significant rains occur in April (Woodin and Lindsey 1954).

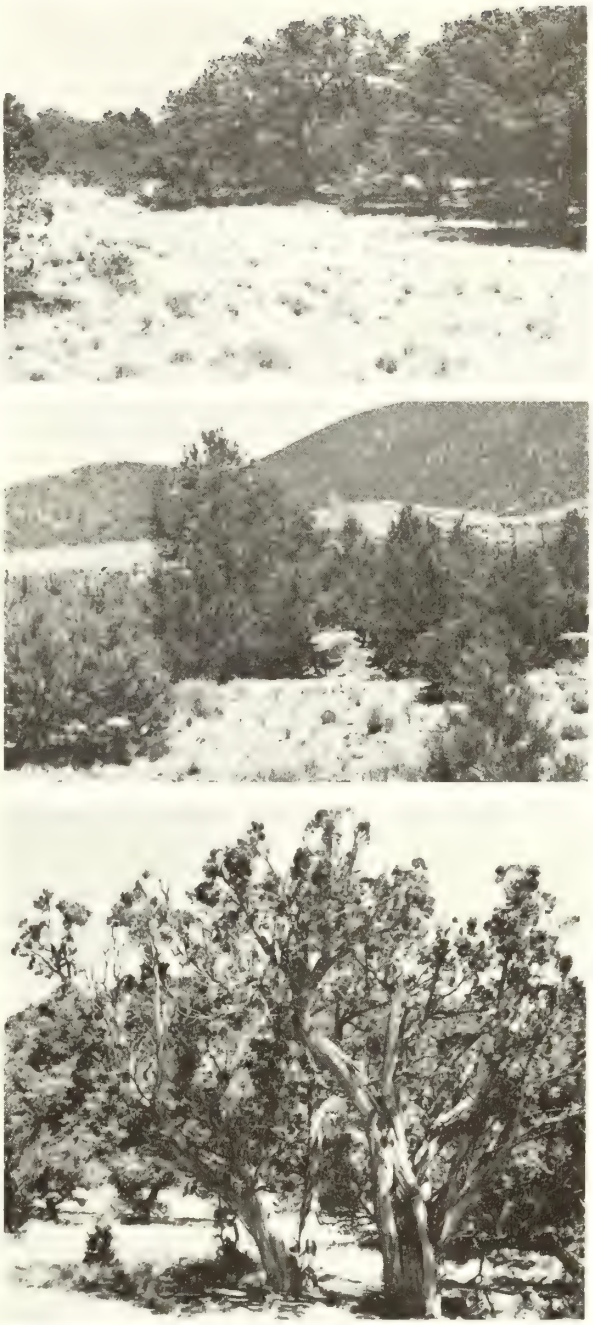
The pinyon-juniper woodland, a climax vegetation, occurs on perhaps 60 million acres, on a variety of different soils derived from limestone, lavas, and sandstones as parent materials. Soils supporting pinyons and junipers are frequently coarse textured, low in organic matter, and alkaline (Barrett 1962). Soil moisture in pinyon-juniper habitats may be deficient during both the spring and autumn droughts characteristic of the Southwest.

Junipers begin growth in the spring, if soil moisture from the winter is adequate, but growth may cease during the spring drought period only to resume again after the summer rains begin. Growth slows again towards the end of the growing season. The capability of junipers to cease and resume growth with changing moisture conditions may account for their ability to survive on dry, exposed sites (Herman 1956).

Variations in resistance to drought and tolerance to frost among pinyons and junipers affect the tree composition of this woodland type. Junipers are generally more drought-resistant than are pinyons, so, they occur at lower altitudes and survive droughts better. Pinyon-junipers are characterized by slow rates of growth, and mature trees in pinyon-juniper woodland may be 200 or 300 years old. There are obvious differences in annual rainfall, summer rainfall, length of growth season, and severity of winter and summer climates in the broad pinyon-juniper woodland zone. Overall, the climate of the pinyon-juniper type is rather severe for tree growth, characterized by relatively low precipitation, hot summers, high wind, low relative humidity, very high evapotranspiration rates, and much clear weather with intense sunlight (Clary et al. 1974).

Pinyon-juniper woodlands vary from very dense to relatively open stands with only occasional trees. Tree density and other ecological considerations affect the abundance of midstory shrubs and understory herbage. Pinyons and junipers may inhibit the production of herbage close to the tree (Tueller and Clark 1975), and tree canopies may shield light from understory vegetation. The herbaceous understory may be the only other vegetation present where the pinyon-juniper woodland has invaded a grassland habitat. The woodland may also contain a shrub midstory where pinyon-junipers have invaded habitats where shrubs have been or are an important vegetation form.

Pinyon-juniper woodlands possess a comparatively simple compositon. All the major understory species within the woodland are also found in the adjacent forest, grasslands, or shrub steppes (West et al. 1975). Sagebrush (*Artemisia* spp.), bitterbrush (*Purshia* spp.), and rabbitbrush (*Chrysothamnus* spp.), and a variety of cold season herbages occur in northern and western pinyon-juniper woodlands. Apache-plume (*Fallugia paradoxa*), a variety of oaks (*Quercus* spp.), manzanita (*Arctostaphylos* spp.), and a variety of warm season herbages occur with the pinyon-junipers in the southern and eastern woodlands (West et al. 1975).



Pinyon-juniper stands range from relatively dense, pure stands of pinyon (top) to intermixtures of the species (center). At lower elevations, Utah juniper forms extensive open stands (bottom).

Animals Inhabiting Pinyon-Juniper Woodlands

Birds

Pinyon-juniper woodlands vary in their successional state, floristic composition and microclimate. As a regional vegetation type, the woodlands provide a varied habitat for wildlife. Junipers are preferred for nesting by birds, possibly because of their shape, the numbers of cavities within their trunk, and the stringy and fibrous bark which provides a quality nesting material. Birds like the pinyon jay (*Gymnorhinus cyanocephalus*), plain titmouse (*Parus inornatus*) and common bushtit (*Psaltriparus minimus*) are obligate to these woodlands (Hardy 1945). He also lists 14 other species that nested within pinyon-juniper woodlands in east central Utah. Scott and Patton (1975) list 26 bird species that are cavity nesters in pinyon-juniper woodlands, and Frischknecht (1975) notes six species of raptors also nesting in this type. Hardy (1945) identified at least 79 bird species that were present in his Utah study area either as summer, winter or permanent residents. A total of 144 different species of birds has been observed in pinyon-juniper habitat at Fort Bayard in southwestern New Mexico. Future studies may show that many bird species which are summer residents throughout the pinyon-juniper type nest within these woodlands.

Besides providing nesting cover, pinyon-juniper trees provide seeds and berries that are eaten by many bird species as well as other vertebrates and invertebrates which, in turn, may be important in avian foodchains.

Reptiles and Insects

The reptile and invertebrate populations are not as abundant in the pinyon-juniper as they are in warmer and more humid forest environments. Frischknecht (1975) summarizes literature indicating that insectivorous and cannibalistic lizards, horned toads and a variety of snakes, including rattlesnakes, have been reported from pinyon-juniper woodlands. Spiders and insects from the Chermidae, Formicidae, Ichneumonidae, Diptera, Cicadellidae, Hemiptera, Coleoptera, and Othoptera groups were collected from the pinyon-juniper woodlands on the Kaibab plateau. A variety of midges, moths, and beetles may damage reproductive tissues of junipers. The nature of the vegetation growing in association with pinyon and juniper trees further modifies the invertebrate fauna present (Frischknecht 1975).

Small Mammals

Pinyon-juniper woodlands occupy a belt between the desert grassland, desert shrub, chaparral, and the coniferous forests. A variety of small mammals extends into the pinyon-junipers from both warm and dry lower, and cool and wet higher habitats. Some species such as pinyon mice (*Peromyscus truei*) and some wood rats (*Neotoma* spp.) seem more-or-less restricted to the pinyon-juniper type. Small carnivores like gray foxes (*Urocyon cinereoargenteus*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), weasels (*Mustela* spp.), skunks (*Mephitis* spp.), badgers (*Taxidea taxus*) and ringtails (*Bassariscus astutus*) search for prey in pinyon-juniper woodlands.

The inner bark of pinyon twigs has been reported by Reynolds (1966) to be eaten by Abert squirrels. Ringtails, racoons (*Procyon lotor*), coyotes, gray foxes, rabbits, and numerous rodents have been reported to eat berries and seeds from junipers and pinyons (Martin, Zim, and Nelson 1961).

Large Mammals

Pinyon-juniper woodlands have great value as habitat for large mammals. Mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and elk (*Cervus canadensis*) may occur throughout the year in certain pinyon-juniper ranges in Arizona and New Mexico. Other mule deer and elk herds throughout the West depend on this habitat as deep snows in and above the yellow pine belt force large concentrations of animals from high summer ranges into the pinyon-juniper zone. Pronghorn antelope (*Antilocapra americana*) may use some pinyon-juniper ranges for important cover as usual grassland habitats become more accessible to man. Frischknecht (1975) indicated that desert bighorn sheep (*Ovis canadensis* nelsoni) utilize those pinyon-juniper ranges in rough areas which are otherwise suitable for bighorn habitat. Buffalo (*Bison bison*) roam pinyon-juniper range in southern Utah, and wild horses extensively use pinyon-juniper woodland in various parts of the West. Undoubtedly, the greatest use of forage within the type is by domestic stock which, when not carefully regulated, may utilize and trample foodstuffs required by wild herbivores. Large carnivores like mountain lions (*Felis concolor*) and bears (*Euarctos americanus*) also feed within this habitat.

Leaves and fruit of pinyon and juniper trees are eaten by pronghorn antelope, mule and white-tailed deer, elk and mountain sheep (Martin et al. 1961) as well as domestic stock. Juniper foliage ranged from 1% to 38% of the contents of deer stomachs collected throughout the West



Merriam's turkey is a frequent inhabitor of pinyon-juniper stands.



Pinyon-juniper trees and whiteface cattle in a savannah setting present a pleasing scene in the west.

(Anderson et al. 1965, Boeker et al. 1972, McCulloch 1969). Palatability of juniper foliage varies according to the species of the tree, among individual trees, and with the availability of other foods (Frischknecht 1975, Jobman 1972). Juniper foliage also comprised 34% of the contents of elk stomachs collected during winter from New Mexico (Short et al. 1977).

The quantity and compostion of the vegetation growing in association with pinyon-juniper influence the importance of pinyon-juniper woodland as big game habitat. The usefulness of midstory and understory plants as food for game animals has been indicated in several food habit studies (Kufeld et al. 1973). Neff (1974), working in natural pinyon-juniper woodlands on the Beaver Creek watersheds in central Arizona, lists browse from such dwarf trees and shrubs as mountainmahogany (*Cercocarpus breviflorus*), desert ceanothus (*Ceanothus greggii*), shrub live oak (*Quercus turbinella*), wavyleaf oak (*Q. undulata*), Gambel oak (*Q. gambelii*), cliffrose (*Cowania mexicana*), and plant parts of wright eriogonum (*Eriogonum wrightii*) and sulfur eriogonum (*E. cognatum*) as seasonally important foods for deer. A large variety of other midstory and understory plants is also consumed, but account for lesser portions of the overall diet of deer. Sagebrush is a major food of deer in pinyon-juniper woodlands in several states (Kufeld et al. 1973). Sagebrush exceeded 70% of the mean contents of the stomach of deer on overcrowded ranges and 50% of the contents of the stomach of deer after deer and cattle populations were reduced on Kaibab winter range. At Fort Bayard, leaves of mountainmahogany and oaks are important in the diet of mule deer at all seasons, and various forbs are important in spring and summer (Boeker et al. 1972). Elk also browse shrubs at all seasons and consume forbs during summer, and grasses during summer and autumn (Short et al. 1977).

The pinyon-juniper woodland is generally a climax vegetation type throughout its range. The trend is toward increased tree density and, finally, a dense canopy cover. Inverse relationships exist between tree basal area and the amount of woodland ground cover (Woodin and Lindsey 1954). Except for foods produced by pinyons and junipers, total food production and the variety of plant foods produced decline with the increasing maturity of pinyon-juniper woodlands.

Total small mammal and bird populations may diminish as the woodland canopy becomes more dense. Habitat diversity is lessened, and those species using midstory and understory plants for habitat and food should be expected to diminish as the midstory and understory plants become less important. A few species like pinyon mice and pinyon jays may, however, be favored as the woodland becomes more dense. Deer and elk use, as measured by pellet group indices, declined as tree canopies became more dense at Fort Bayard in southwestern New Mexico (Short et al. 1977). Perhaps this occurred because the production of more desirable foods is drastically reduced in dense pinyon-juniper stands. Usefulness of the habitat to domestic stock is also reduced as the herbaceous understory declines.

Open stands of pinyon-juniper with abundant midstory and understory vegetation seem most favorable to many wildlife species. Manipulation of dense pinyon-juniper woodlands to provide this habitat diversity is desirable habitat management for many species. Unfortunately, the greatest livestock productivity of some pinyon-juniper ranges is realized with the clear-cutting of the woodland and the establishment of a grass cover. This treatment may be unfavorable for many wildlife species and may represent a major destruction of wildlife habitat. For public lands, at least, it is desirable to weigh the requirements of both wildlife and the domestic livestock industry when managing pinyon-juniper woodlands.



Bulldozing can be used either to destroy or to manage, pinyon-juniper woodland.

Wildlife Habitat Management In Pinyon-Juniper Woodlands

Economic Considerations

Much of the early pinyon-juniper management was simply an attempt to clear as much woodland as cheaply as possible. Dragging a heavy cable or anchor chain between two large tractors to uproot trees and brush was, and still is, the most common mechanical control. Bulldozers, tree crushers and chainsaws have also been used. Large blocks of woodland were cleared with little regard for any impact on wildlife or for aesthetic considerations. Downed trees were usually windrowed or piled and burned. From 1945 to 1965, control was mostly an attempt to improve range for domestic livestock.

Modification of dense stands of pinyon-juniper has always been expensive. Large woodland control operations are expensive because of the low demand and market value for timber products such as fuelwood, fenceposts, lumber, veneer, resins, and pulpwood (Arnold et al. 1964). Benefits from pinyon-juniper clearing have largely come from the value of additional livestock forages produced when the tree canopy is removed. Forage production, however, varies greatly between clearing sites due to differences in soil fertility and soil water retention capabilities. Only when posttreatment forage production is high, do benefits equal or exceed the costs of clearing pinyon-juniper woodlands using mechanical techniques (Clary et al. 1974). Although pinyon-juniper woodlands comprise vast acreages, there is little opportunity to appreciably increase water runoff from these semiarid lands because of their high evapotranspiration rates and, therefore, little justification for large-scale pinyon-juniper conversions as watershed improvement practices (Clary 1975).

Some management of pinyon-juniper woodlands is justified to increase the yield of products which can be cropped from this type. Some areas near metropolitan centers can be managed both for the production of Christmas trees and pinyon nuts. Junipers can also be selectively harvested for firewood, fenceposts and various wood products such as charcoal. In the future, pulp and a variety of other wood products may be obtained from this forest type. Clearly greater economic use could be made of the woodland products. Almost any use that selectively harvests individual trees or small groups of trees seems compatible with the management of important wildlife species.

Livestock vs. Wildlife

Management of pinyon-juniper woodlands for wildlife and for range stock varies in the degree of overstory removal. There is greater multiple use value in the partial removal of the overstory or in clearing only small blocks of pinyon-juniper woodland to produce some additional forage. Large clearings which might produce abundant herbage for livestock might also destroy extensive blocks of wildlife habitat.

Pinyon-juniper woodlands are quite important for livestock grazing because of their size and because their climate is frequently favorable to range animals. The woodlands provide critical spring and autumn range for many cattle and sheep. Complete clearing of pinyon-juniper woodlands to increase herbage production for livestock may be economically justified on highly productive grassland sites where little wildlife use occurs and herbage productivity has been drastically reduced by invading trees. Any public land considered for a conversion treatment should be

intensively surveyed to determine its potential for herbage production and its present value as wildlife habitat. Results from mammalian surveys, bird censuses, and the presence or absence of desirable midstory shrubs are indicators of wildlife habitat values. It is difficult to justify the conversion of woodland which serves as important winter range for deer and elk, or which provides important habitat for some uncommon, rare or endangered species. It is equally difficult to justify large conversion treatments on areas with the potential for producing only low to marginal amounts of additional herbaceous forage after treatment.

Cattle, sheep and horses primarily consume grass. They also eat forbs, browse leaves, seeds, and fruits—items important to both game and nongame wildlife. Heavy consumption of these latter forages by livestock from spring to early autumn may eliminate foods required by wildlife during late autumn and winter. Livestock grazing pressures have to be managed in some areas so that seasonal grazing does not permanently damage vegetation and soil or destroy wildlife forage.

Overgrazing and trampling by cattle and sheep may have contributed to the recent invasion of junipers into areas that were formerly juniper savannahs or grassland inclusions within the pinyon-juniper woodlands (Johnsen 1962). Other grasslands, at lower elevations, may have drier and warmer summers and may not be as susceptible to invasion. Short droughts are detrimental to the establishment of junipers in grasslands because dormant grasses are not as severely affected as juvenile trees. Large trees with established root systems withstand drought conditions better than grasses, however (Johnsen 1962). Established junipers thus become dominant during droughts. Large junipers also are not killed as readily by grass fires. Reduction in herbaceous competition and lack of grass fires, since fire suppression has become so efficient, have probably accelerated the invasion of junipers into suitable grasslands (Johnsen 1962).

Role of Fire

Pinyon-juniper trees are frequently hit by lightning during summer storms. Burning trees that endanger manmade structures or commercial forests require prompt fire suppression efforts. Dense pinyon-juniper woodlands usually have limited fuels to carry fires because of the inverse relationship between tree canopy cover and the herbaceous understory. A crown fire, even with high wind and low humidity, will carry only where the canopy cover is very dense. It will suppress itself in areas where the pinyon-juniper density is reduced.

Throughout the pinyon-juniper region, charred snags show that wildfires have helped maintain openings in many pinyon-juniper woodlands. Fire produces a patchwork effect which may be desirable even though burned snags may not be esthetically pleasing.

Prescribed fires in pinyon-juniper woodlands burn slash, kill individually ignited trees, and open some pinyon-juniper woodlands that contain sufficient herbaceous cover to carry fire (Blackburn and Bruner 1975). Alligator junipers and some browse species resprout following fire. Small burns seem more desirable for deer because they create a greater variety of food and cover conditions than do larger burned or unburned areas (McCulloch 1969). Large burned areas may be conditionally acceptable to deer if in remote areas (McCulloch 1969).

Role of Herbicides

Mechanical clearing of woodlands is expensive. As labor and equipment prices soar, there may well be less justification for mechanical range improvement practices in the future. Aerial application of herbicides then becomes potentially important as an alternate method for modifying pinyon-juniper stands. If herbicides could be safely used, their aerial broadcast could create numerous, small, irregularly-shaped openings in terrain that is too rough for mechanical operations. Herbicides may also offer some potential in managing pinyon-juniper woodlands for increased water yields (Clary et al. 1974).

The possibility of destroying midstory shrubs important as food sources, and the esthetically distasteful appearance of dead snags are major disadvantages to herbicide use. Perhaps the greatest disadvantage, however, is the danger that the gross misuse of chemicals might destroy rather than manage a forest type that is important to wildlife in the United States.

Recommendations

The effect of pinyon-juniper manipulation on most wildlife species is not known. Reestablishment of very early successional stages to maximize grass production will favor some wildlife species, while the thinning of mature pinyon-juniper woodlands to provide a mixture of grass,

forbs, shrubs, and trees will favor other species, such as mule deer. The clearing of pinyon-juniper woodlands may, on the other hand, destroy habitat for pinyon jays, pinyon mice, and brush mice. Management of woodlands to favor big game like mule deer may include the following recommendations.

Pinyon-juniper management should be restricted to areas intensively utilized by big game, especially during the winter. Management should provide many small cleared areas interspersed with natural woodland. This arrangement provides greatest "edge" which results in a maximum diversity of vegetation forms. Pinyon-juniper management to favor deer should be confined to extensive and dense stands which are more than one-half mile wide, with average crown cover exceeding 20% and an overall stocking rate greater than 75 trees per acre (McCulloch 1973). Such woodlands, if pinyon-juniper trees are 10 inches or more in diameter, will have a tree basal area of 40 or more square feet per acre. They will also generally have a scarcity of herbaceous and shrubby forages in the mid- and understory. Woodland management thus attempts to restore open stand conditions which may have closed over the last 75 years because of overgrazing, fire suppression, or other conditions.

Woodland openings should be between 100 and 600 feet wide (McCulloch 1973). Wider clearings may be acceptable in very remote areas. Cleared strips should follow natural physical boundaries and assume irregular shapes to be esthetically pleasing. Slash and woody debris should be retained in the numerous small openings. Light to moderate spring and autumn grazing of grasses by cattle is acceptable, but cattle should be fenced from important browse slopes. Sheep should not be allowed to graze areas that are used as winter range by big game (Terrel and Spillett 1975). Uncleared strips of woodland should be at least as wide as cleared strips. Buffer zones of uncleared pinyon-juniper woodland one-fourth-mile wide should be retained along highways, scenic and recreational areas (McCulloch 1973) and archeological sites.

Large junipers in savannah setting are esthetically pleasing, furnish shade, and provide food for wildlife. Removing such trees sacrifices the important cool season forage that grows under the canopy for the possible increased production of an already abundant warm season forage that might have grown in the tree's absence (Clary and Morrison 1973).

Slopes up to 40% in the pinyon-juniper type are used by deer and elk at Fort Bayard (Reynolds 1964). Slopes greater than 15% should not generally be subjected to mechanical clearing or herbicidal treatment because of the possibility of erosion, and the probability that only limited herbage would be produced for livestock.

Large clearings of pinyon-junipers in cold climates will not offer sufficient cover for either deer or cattle during severe winter weather (Neff 1972). Cleared areas should consequently be relatively small and well dispersed within the woodland. Neff (1972) found that clearings up to 330 acres would be used by deer in good weather if shrub oak thickets were retained to provide some cover, acorn crops, and some moderately palatable browse.

Blocks of pinyon-juniper woodlands at Fort Bayard were used less by deer and elk after they had been cleared, and the resulting large clearings tended to disrupt use of the contiguous blocks of pinyon-juniper woodlands that were isolated by the clearings (Short et al. 1977). Scott and Boeker (1977) reported that large conversions of pinyon-juniper woodlands disrupted the use of the habitat by wild turkeys. Many wild species use the edge of clearings where vegetation diversity is greatest. As clearings increase in size, the ratio of edge to total clearing area diminishes and land area is effectively removed as habitat from the woodland type.

Trees should be mechanically removed by methods that will not deplete palatable shrubs. Bulldozing is preferable to cabling on areas supporting large browse plants (McCulloch 1973). The slash, if left scattered and intact, will provide habitat for rabbits, rodents, birds, and big game, and may protect newly established forage plants from excessive use by game and livestock. The variety and abundance of vegetation and rodents was greater on an area of the Kaibab Plateau of northern Arizona that contained slash from recently uprooted pinyon and juniper trees (Turkowski and Reynolds 1970). Populations of small mammals frequently increase for about 3 years following pinyon-juniper conversion treatments (Terrel and Spillett 1975). Numbers of pinyon mice and brush mice, however, usually decline following woodland clearing. Numbers of carnivores in pinyon-juniper treatment areas should be expected to fluctuate as do small mammal populations.

Modified pinyon-juniper woodlands can be reseeded to improve wildlife habitat. The seasons and procedures for planting grasses, forbs, and shrubs in Utah have been listed by Plummer et al. (1968). Seeding a mixture of grasses, forbs (including sweet clover and alfalfa) and shrubs (in-

cluding sagebrush, rabbitbrush and antelope bitterbrush) in late fall through winter before or between mechanical tree clearing operations yielded best results. Sometimes, broadleaved herbaceous species respond well after mechanical clearing without any reseeding. Livestock grazing on rejuvenated lands must be carefully controlled. A healthy grass, forb and shrub community in combination with controlled browsing pressure is important in preventing pinyon-juniper from regaining dominance on treated lands (Stevens et al. 1975). Pinyon-juniper control will also release browse species growing in the midstory, so that current forage production is appreciably increased (McCulloch 1966). Grass yields only increase slowly, however, on sites where few native grass remnants existed prior to pinyon-juniper modification (Clary 1971). Grasses should be reseeded while the soil is still disturbed or just prior to any cabling or chaining operation.

Management Implications

Future demands for products from pinyon-juniper woodlands will probably cause, as Johnson (1975) suggests, all pinyon-juniper units on public lands to be classified according to their potential for management. Much of the woodland will remain intact and will produce some forage for livestock and some cover and food for wildlife. Some areas that have good potential for herbage production and which are not heavily used by wildlife will be converted to produce foods for livestock. Some additional conversion of woodlands will also occur to stabilize highly erodible soils. Because food production is reduced as the woodland canopy becomes dense, some woodlands comprising wildlife winter range will be opened. Small irregularly-shaped openings or narrow contour strips, especially if seeded with important foodstuffs, will provide food, while surrounding natural woodlands will provide cover.

The continued development of stock tanks throughout the woodland will aid both wildlife and livestock. Livestock grazing on public lands throughout the woodland should be more rigorously managed than at present. Treated woodland, that has been successfully converted to productive grasslands, should obtain relatively more grazing pressure than those vast areas of woodland whose conversion cannot be justified. Very little livestock grazing should occur on those public lands that are important wildlife winter range. Important browse slopes within the woodlands should be restricted to use by wildlife. The harvest of pinyon-junipers for woodland products, if done on a selective tree cutting basis or in a manner that results in the clearing of only small areas of woodland, in most cases, will not be incompatible with wildlife use of the woodlands.

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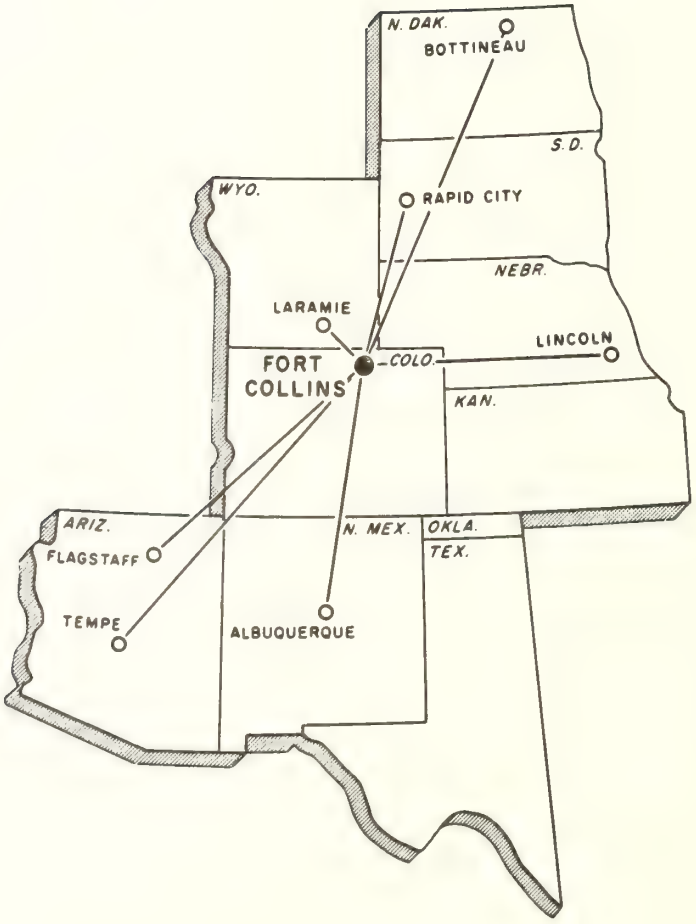
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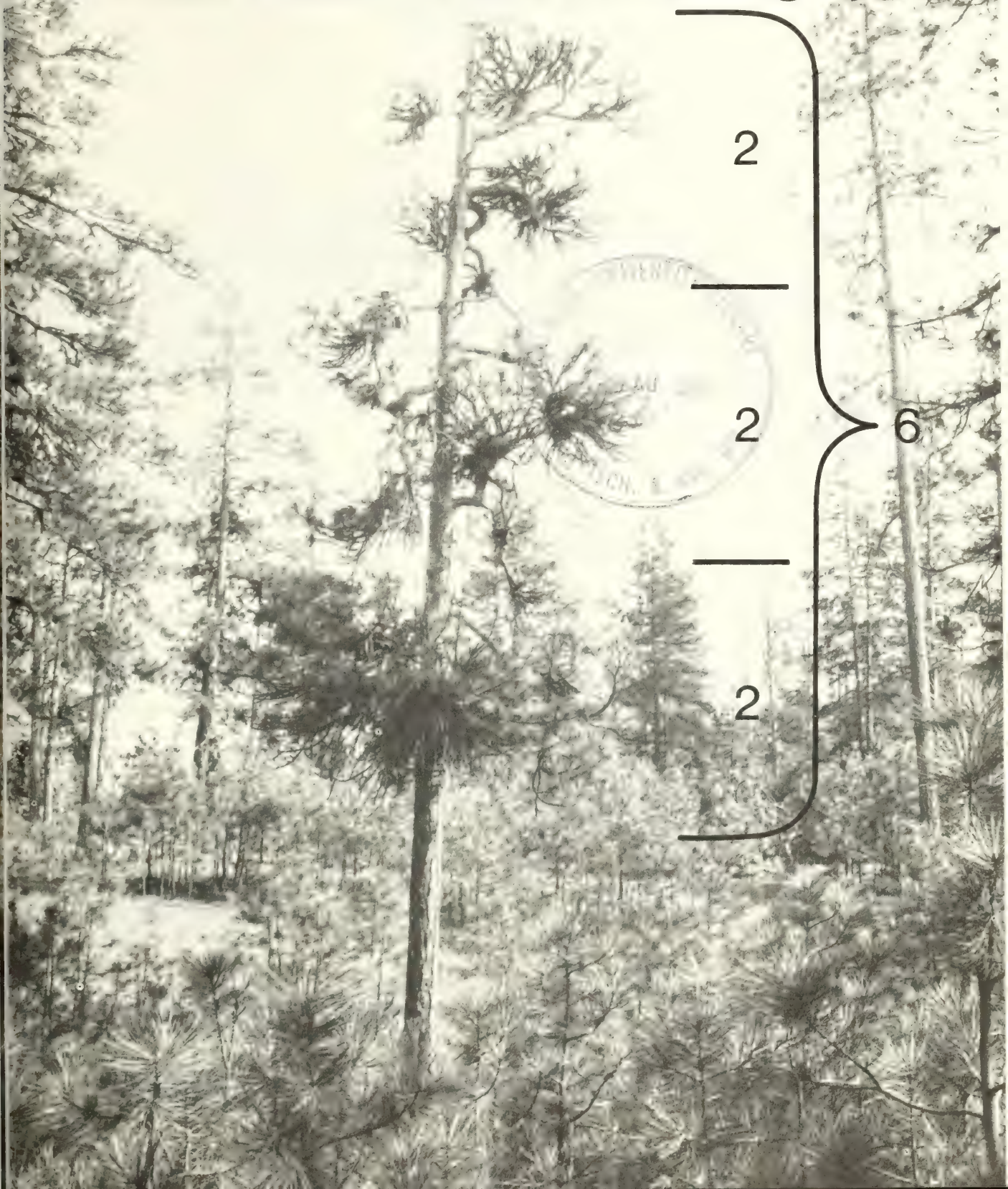
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A Forest Service
eral Technical Report RM-48
mber 1977

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Fort Collins, Colorado 80521

ne 6-Class Dwarf Mistletoe Rating System



USDA Forest Service
General Technical Report RM-48

December 1977

The 6-Class Dwarf Mistletoe Rating System

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Abstract

Several rating systems have been proposed to describe the intensity of dwarf mistletoe infection in individual trees or stands, but the 6-class dwarf mistletoe rating (DMR) system, described in 1956, has been most widely adopted. This system is being used for several dwarf mistletoe host/parasite combinations in western North America. Uses and limitations of the 6-class system are discussed, and several applications of the system are cited.

[1] *Central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

The 6-Class Dwarf Mistletoe Rating System

Frank G. Hawksworth

Introduction

During the period since the introduction of the 6-class dwarf mistletoe rating sytem (Hawksworth and Lusher 1956), it has become the generally accepted standard in the western United States and western Canada. This paper discusses dwarf mistletoe rating systems in general, the 6-class system in detail, and the uses and limitations of the 6-class system.

Rating Systems

Dwarf mistletoe rating systems are useful to: (1) quantify the degree of infection so that stand management priorities can be established, (2) aid quantification and estimation of growth loss and mortality, (3) help define which trees are suitable for seed trees, and (4) help quantify the mistletoe-infection hazard of overstory trees or stands to understory stands.

There have been several attempts to quantify dwarf mistletoe intensity on a tree basis (table 1). Some of these systems have used as few as 4 classes (including uninfected trees) and one as many as 18. In many of these classifications, and indeed in many dwarf mistletoe publications, infection intensity is rated as "light," "medium" or "heavy," but these terms have not been defined.

Some of the classification systems attempt to quantify the proportion of the crown broomed, others quantify the proportion of crown infected, while some utilize a combination of both types.

This plethora of rating systems makes it impossible to directly compare results of different studies. Thus, the 6-class system was designed to fill the need for a more uniform, less subjective, rating system.

The 6-Class Rating System

The 6-class dwarf mistletoe rating system was first used in 1951. It was first mentioned as a footnote in a paper by Hawksworth and Lusher (1956) and later described in more detail by Hawksworth (1961, p. 77) and Baranyay and others (1971). The system has six intensity classes of mistletoe infection plus one for noninfected trees. For this reason perhaps it should have been referred to as the "7-class" system. However, since the name "6-class" has been widely used in the literature for many years and has not been the source of confusion, I suggest continuance of the "6-class" designation.

Description

For this system the live crown is divided into thirds, and each third is rated as: 0, no mistletoe; 1, light mistletoe (less than half of the branches infected); and 2, heavy mistletoe (more than half of the branches infected). The ratings of each third are added to obtain a total for the tree. For example, a tree heavily infected in the lower third of the crown, lightly infected in the middle third, and not infected in the upper third, would be Class 3. A tree heavily infected in each third would be Class 6 (fig. 1). The system is simple to use, and different observers tend to rate an infected tree similarly.

A tree with an infection on the bole, but not the branches, is rated as Class 1. Otherwise, bole infections are not considered in the rating system.

Abbreviations which will be used in this paper are DMR, for a tree rating using the 6-class system, and DMR for a stand rating.

The 6-class system was originally used for *Arceuthobium vaginatum* subsp. *cryptopodum*

Table 1.—Rating systems used for dwarf mistletoe-infected trees

Arceuthobium species (and host)	Number of classes (including healthy)	Description	Reference
A. laricis (western larch)	5	0, healthy trees; infected rated X, XX, XXX, or XXXX based on degree of infection (not defined).	Weir 1916
A. vaginatum subsp. *cryptopodum* (ponderosa pine)	4	0, healthy trees without mistletoe; X, light mistletoe infection; XX, medium mistletoe infection; XXX, heavy mistletoe infection.	Korstian and Long 1922
A. americanum (jack pine)	4	0, healthy tree; X, slightly infected tree; XX, severely infected tree; XXX, very badly broomed tree.	Dowding 1929
A. douglasii (Douglas-fir) and *A. vaginatum* subsp. *cryptopodum* (ponderosa pine)	7	Six class system. Each third of a live crown rated as 0, no mistletoe; 1, less than half the branches infected; or 2, more than half the branches infected. Ratings of each third totaled for this rating. Ratings range from 0 (uninfected tree) to 6 (heavily infected). (Described in more detail in this paper).	Hawksworth and Lusher 1956, Hawksworth 1961
A. douglasii (Douglas-fir) and *A. laricis* (western larch)	4	"None" - No visible infection; "Light" - less than one-third of crown broomed; "Medium" - one to two thirds of crown broomed; "Heavy" - more than two-thirds of crown broomed.	Pierce 1960
A. douglasii (Douglas-fir)	4	Class I - No evidence of brooming; Class II - brooming confined to lower third of live crown; Class III - brooming for at least two-thirds of live crown; Class IV - brooming for at least two-thirds of live crown, and spike top developing.	Shea 1963
Arceuthobium spp. (several hosts in western Montana)	5	Live crown divided into 2 equal parts, each half was rated as 0, no infection; 1, less than one-third of branches infected; or 2, more than one-third of branches infected. Total for each half of crown added for tree totals which range from 0 (no infection) to 4 (very heavy infection).	Graham 1964
Arceuthobium spp. (several hosts in NE Washington)	6	Same as above, but with 1 additional class for trees killed within the previous 5 years and showing symptoms or signs of having had dwarf mistletoe.	Graham and Frazier 1962
A. tsugense (western hemlock)	18	Each third of crown rated from 0.0 (no visible infections) to 3.0 (numerous large branch infections in the form of witches' brooms and at least one trunk swelling) by 0.5 class intervals. Rating in each third totaled for tree ratings.	Smith 1969
A. tsugense (western hemlock)	6	Middle-third rating system. Because the lower third of the tree often had numerous dead, broken, and missing branches and because the top third was often partially hidden, an analysis of growth loss in relation to the middle-third rating only was made. The results suggest that middle-third rating is superior to whole-tree rating.	Smith 1969

Arceuthobium species (and host)	Number of classes (including healthy)	Description	Reference
A. americanum (lodgepole pine)	4	0, healthy; 1, light branch infection, less than 50% of crown infected; 2, heavy branch and stem infection, more than 50% of the crown infected; 3, witches' brooms, branch and stem infections, more than 50% of the crown infected.	Baranyay and Safranyik 1970
A. abietinum (true firs)	10	Each third of crown rated as 0, no mistletoe; 1, 1-10% of branches infected; 2, 11-50% of branches infected; and 3, over 50% of branches infected. Totals added for tree rating. Note that by combining classes 1 and 2 in each third, ratings are the same as in the 6-class system.	Scharpf 1977

in ponderosa pine and for *A. douglasii* in Douglas-fir in the Southwest (Hawksworth and Lusher 1956, Andrews and Daniels 1960, Hawksworth 1961). It was later found to be applicable to *A. americanum* in lodgepole pine in the Central Rockies (Hawksworth and Hinds 1964, Myers and others 1971). The system has also been applied to *A. campylopodum* in ponderosa pine in the Pacific Northwest (Shea 1964, Flora 1966), *A. occidentale* in Digger pine in California (Hawksworth 1969), and *A. cyanocarpum* on limber pine in Colorado (Hawksworth and others 1975).

The 6-class system is also being widely used in western Canada: in British Columbia for *A. americanum* in *Pinus contorta* (Dobie and Britneff 1975), *A. tsugense* in *Tsuga heterophylla* and *Pinus contorta* var. *contorta* (Smith and Wass 1976), and *Arceuthobium* spp. (Baranyay and Smith 1972).

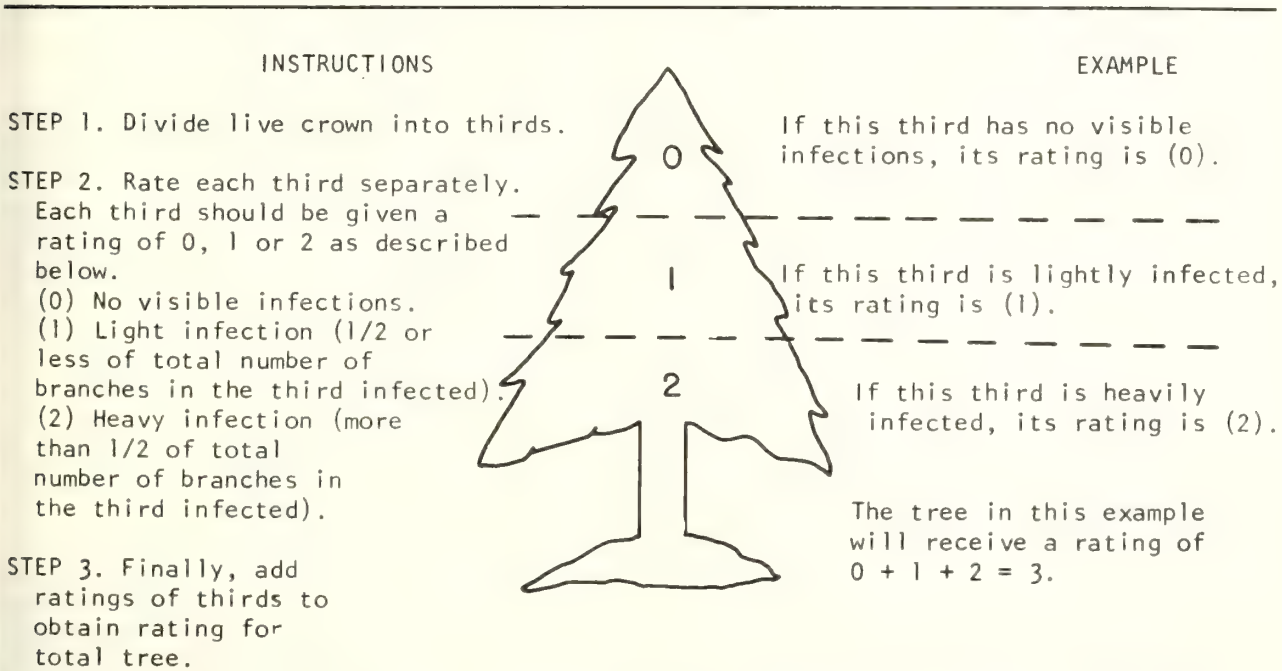


Figure 1—The 6-class mistletoe rating system [Hawksworth 1961].

The 6-class system has been questioned since it does not directly consider the degree of brooming in rating a tree. However, the degree of brooming is indirectly considered because frequency of brooming is directly correlated with the infection class. As shown in the following example for *A. vaginatum* subsp. *cryptopodum* on southwestern ponderosa pine, the proportion of trees broomed increases markedly as the infection class increases (Hawksworth 1961).

DMR	Broomed trees as percent of trees infected
1	3
2	4
3	16
4	36
5	61
6	68

Growth of moderately or heavily broomed trees is more adversely affected than growth of the non- or slightly broomed trees of the same class (Hawksworth 1961). The above tabulation shows that, when trees are grouped by infection classes, the brooming is accounted for because brooming is related to infection class. No comparable data are available for other host/parasite combinations, but the relationship is probably similar for them.

The 6-class system has also been criticized because it sometimes tends to overrate lightly infected trees. For example, a tree with two infections—one in the lower third and one in the middle third of the crown—would be rated as Class 2, whereas a tree of comparable size may have several infections and still be rated only as Class 1 if they are all in the same third, and less than half the branches in that third are infected. Scattered infections, however, rarely occur throughout the crown. Infection normally takes place first in the lower third of the crown and spreads upward. A Class 2 tree typically has only the lower third of the crown infected; Class 3, the lower half; Class 4, the lower two-thirds, etc.

In the 6-class system, dwarf mistletoe in each third of the crown is given equal weight. However, the actual crown volume in each third of a tree is normally not the same—that is, the volume of the lower third is usually greater than the upper third. This is somewhat offset, however, by the fact that mistletoe in the lower third of the crown has much less effect on growth of the tree than the same amount of infection in the upper third. For this reason, and because it would complicate the rating system and make it more difficult to apply, unequal weighting by thirds probably would not be useful on a practical basis.

Most analyses of $\overline{\text{DMR}}$ on a stand basis have been in even-aged or two-aged stands. In these cases, $\overline{\text{DMR}}$ for the stand or story adequately describes the mistletoe situation. However, average $\overline{\text{DMR}}$ may not be as meaningful for all-aged, irregular stands, and a $\overline{\text{DMR}}$ based only on the dominant trees may be needed.

Limitations

The 6-class system can be applied to trees of any size class, but in practice it is difficult to use for very small trees.[2] Specifically, it is not recommended for trees under about 10 feet tall. Application of the system is also difficult for small, suppressed trees with sparse crowns, or for dense pole-sized trees with very short crowns. Since such trees usually constitute only a small proportion of a stand, however, the overall results on a stand basis are usually little affected if the system is applied to these trees.

The 6-class, or any system that requires rating tops of trees, also may not be practical in dense stands of very tall trees. For example, Smith (1969) found it difficult to examine the tops of trees in dense western hemlock stands in coastal British Columbia, so he devised a rating system based only on the amount of infection in the middle third of the crown.

The 6-class system is useful in evaluating the effects of the parasite on growth of infected trees, but it does not necessarily provide a measure of the infection potential of a tree. For example, a Class 6 tree may be of such poor vigor that it is producing fewer mistletoe seeds than a more vigorous Class 2 tree.

[2] *A modification used for small lodgepole pines in interior British Columbia is to divide the crown in thirds in the usual manner but to rate intensity on number of infections rather than proportion of branches infected, e.g. one to three infections in each third would rate a "1", and four or more infections would rate a "2". Personnel communication, Allan Van Sickle, Pacific Forest Research Centre, Victoria, B.C., 1977.*

Table 2.—Distribution of dwarf mistletoe by classes and average stand ratings for 41 even-aged lodgepole pine plots (0.02 to 0.43 acre) in Colorado and Wyoming (Data from research reported by Myers et al. 1971)

Plot $\overline{DMR}$ range	No. of plots	Observed average plot $\overline{DMR}$	Distribution of trees by DMR classes						
			0	1	2	3	4	5	6
			Percent						
0.1 - 1.0	10	0.1	95	3	1	1	0	0	0
1.1 - 2.0	5	1.5	47	15	11	13	9	4	1
2.1 - 3.0	9	2.8	8	14	18	30	18	8	4
3.1 - 4.0	6	3.5	3	6	11	27	31	16	6
4.1 - 5.0	7	4.6	1	2	5	12	20	30	30
5.1 - 6.0	4	5.3	1	1	3	5	10	17	63

Application of The 6-Class System

The primary use of the 6-class system is to quantify the intensity of infection in stands. For the stand average $\overline{DMR}$, the DMR's of each live tree (including healthy ones) are totaled and divided by the number of trees. Table 2 shows how the tree and stand $\overline{DMR}$'s were related for several lodgepole pine plots.

The detail of the 6-class system is not always needed, and classes may be combined. For example, Classes 1 and 2 ("light infection"), 3 and 4 ("moderate infection") and 5 and 6 ("heavy infection") were used by Shea (1964) in a study of the effects of dwarf mistletoe on diameter growth of ponderosa pine in Oregon. When it is necessary to document long-term intensification of dwarf mistletoe in a stand, the full classes should be retained.

Rating individual trees can be time-consuming when a great many trees need to be tallied, so short-cut methods to estimate $\overline{DMR}$ from the percentage of trees infected have been developed for some host/parasite combinations in some types of stands. The relationship between $\overline{DMR}$ and percentage of trees infected has been determined:

1. For lodgepole pine in the Central Rocky Mountains (Myers and others 1971)[3].
   $\log \overline{DMR} = -0.8814 + 0.01492\ P$
   P = percent of trees infected.
2. For ponderosa pine in the Southwest (Myers and others 1976).
   $\log \overline{DMR} = -0.9465 + 0.0165\ P$
   P = percent of trees infected

These equations are for unmanaged stands; they may or may not be applicable in stands that have been thinned, depending on how much consideration was given to mistletoe in marking. It is emphasized that these equations are only approximations and do not account for stand-to-stand variability. Hence, data based on actual $\overline{DMR}$ is more accurate and should be used if available.

[3] *Note: the original published equation is in error.*

Examples of 6-Class System Application

Some examples of how the 6-class system has been used on a tree basis are:

1. To document the growth rate of trees in different infection classes. The last 5 years d.b.h. radial growth in 140-year old, dominant ponderosa pines in relation to DMR was as follows. Mescalero Apache Reservation, New Mexico (Hawksworth 1961.)

DMR	Radial growth *(inches)*	Growth Rate (as a percent of average rate in classes 0-3)
0	0.21	100
1	.21	100
2	.21	100
3	.21	100
4	.19	90
5	.16	76
6	.10	48

2. To document the recurrence of mistletoe in trees pruned to control the parasite. Trees of higher infection classes developed so much mistletoe after pruning that they could not be repruned and had to be killed. Ponderosa pine, Grand Canyon National Park, Arizona (Lightle and Hawksworth 1973).

Original DMR	Percent of trees still alive after 20 years
1	70
2	50
3	40
4	10

Thus, it was concluded that most pruning should be confined to trees of infection Class 1.

3. Dwarf mistletoe is known to adversely affect seed population of the host tree. In the case of ponderosa pine, it is suggested that suitable seed must be of DMR 3 or lower (Myers 1974).

Examples of the use of $\overline{DMR}$ for prediction are:

4. 10-year mortality in even-aged ponderosa pine stands in the Southwest (Myers and others, 1976):

$Y = 20.665 + 4.423X_1 - 0.364X_2 + 3.876X_3$ when,

Y = 10-year mortality in trees per acre

$X_1 = \overline{DMR}$

X_2 = site index (base age 100)

X_3 = number of trees per acre.

5. 10-year periodic height increase in infested stands as a proportion of increase in comparable uninfested stands (Myers and others 1971).

$Y = 1.0 - 0.165X_1$

Y = height decrease proportion.

$X_1 = \overline{DMR}$

Conclusions

Of the 12 dwarf mistletoe rating systems proposed, the 6-class system is most widely used. It is being used for several host/parasite combinations in the western United States and Canada. The 6-class system has been used for many purposes, e.g., to quantify height and diameter growth loss in infected trees; to quantify infection in stands; and to indentify which trees are suitable as seed trees. The system does not, however, necessarily provide a measure of infection potential of a tree as this is frequently not related to the amount of infection in a tree. Thus, while it is recognized that the 6-class system has some limitations and may not be applicable to all host/parasite combinations, it does have the strong attribute of comparability and seems to be the best currently available system for general use.

A description and example of the use of the 6-class system in a plastic coated, wallet-size card has been prepared by the Southwestern Region. These are available from the author or from:

USDA Forest Service
Forest Insect and Disease Management
517 Gold Avenue, S.W.
Albuquerque, N.Mex. 87102

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Several rating systems have been proposed to describe the intensity of dwarf mistletoe infection in individual trees or stands, but the 6-class dwarf mistletoe rating (DMR) system, described in 1956, has been most widely adopted. This system is being used for several dwarf mistletoe host/parasite combinations in western North America. Uses and limitations of the 6-class system are discussed, and several applications of the system are cited.

Keywords: *Arceuthobium,* dwarf mistletoe, forest disease control.

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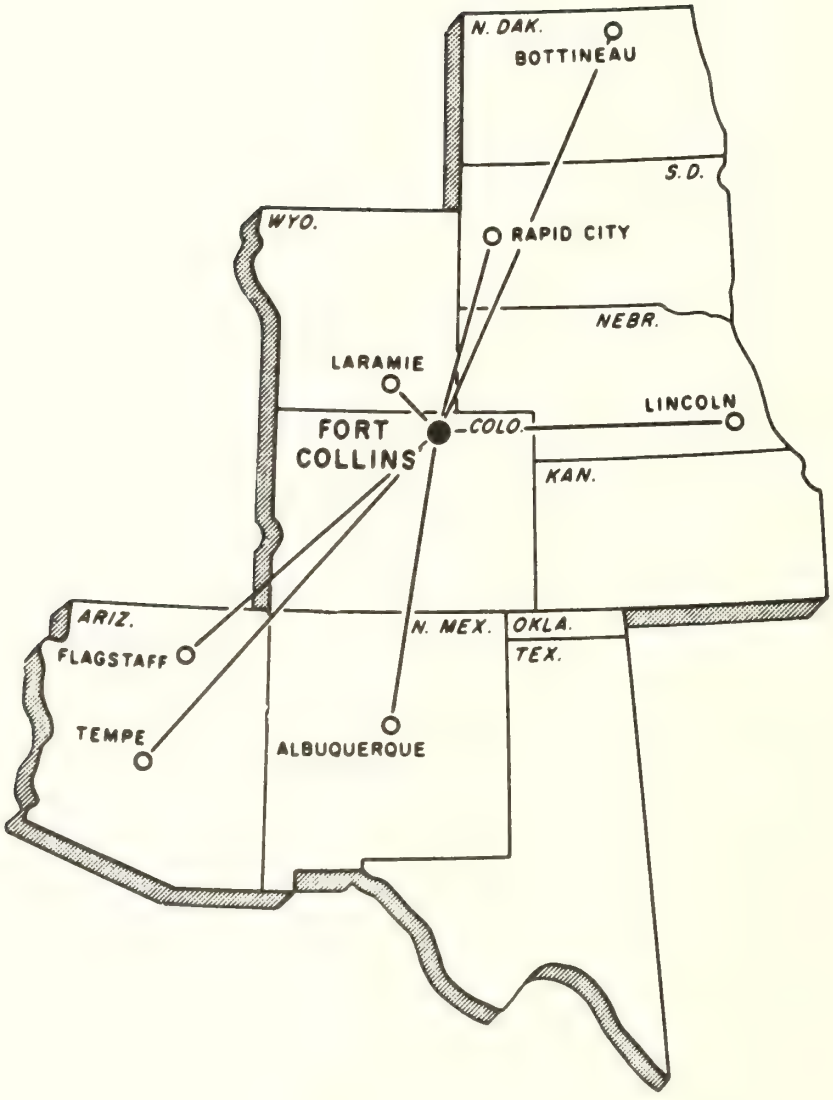
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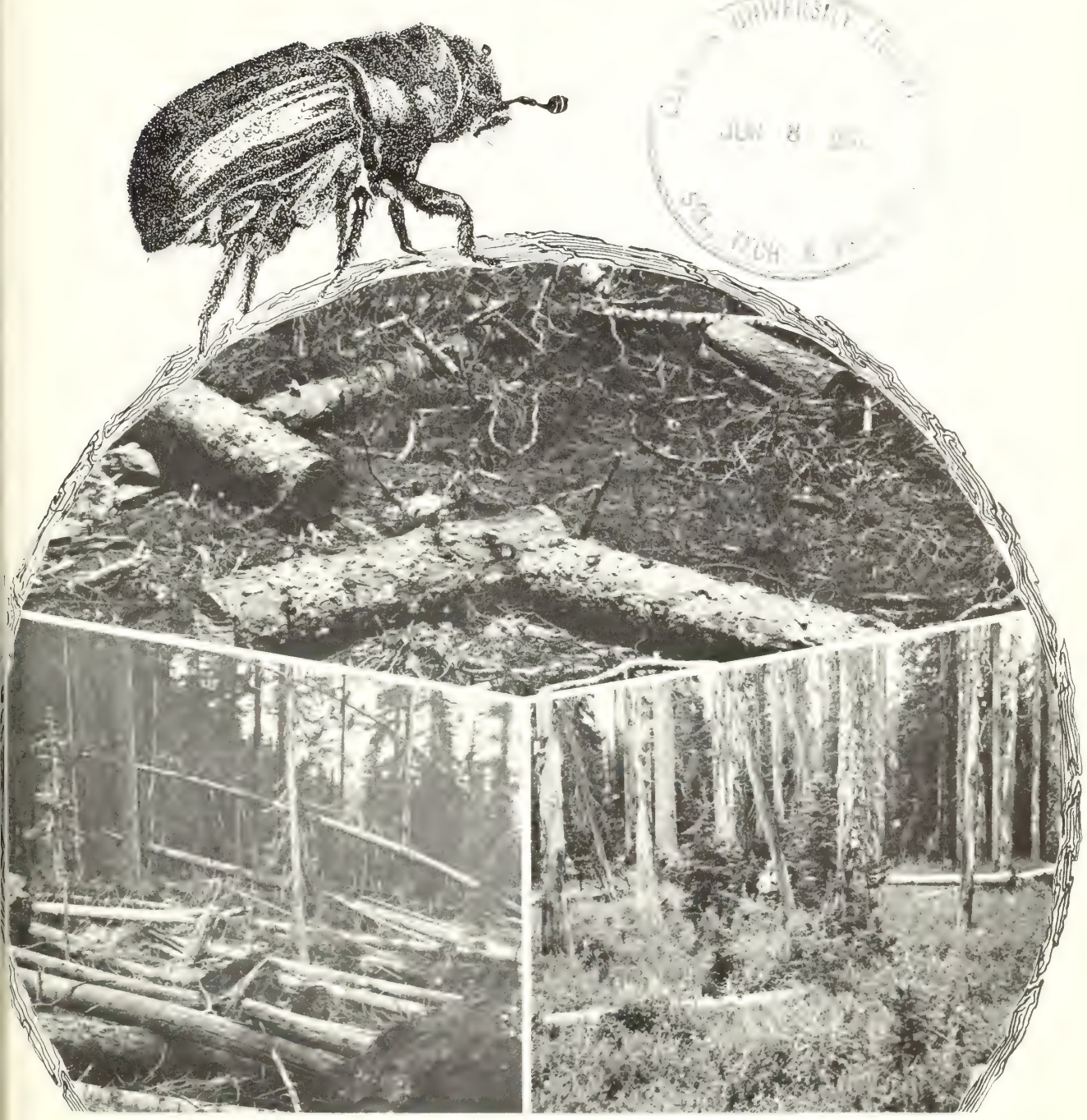
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Spruce Beetle in the Rockies

J. M. Schmid and R. H. Frye



USDA Forest Service
General Technical Report RM-49
December 1977

Rocky Mountain Forest and
Range Experiment Station
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U.S. Department of Agriculture
Fort Collins, Colorado 80521

Abstract

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Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.



The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

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Spruce Beetle in the Rockies

J. M. Schmid, Entomologist
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R. H. Frye, Forester
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Dedication

This paper is dedicated to Dr. Noel Wygant, one of the pioneers in spruce beetle research. Dr. Wygant's knowledge of the White River outbreak and the spruce beetle in general has been generously shared with those of us who followed his early work and pursued spruce beetle research. We consider ourselves privileged to know him.

[1]*Central headquarters is maintained at Fort Collins in cooperation with Colorado State University.*

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Spruce Beetle in the Rockies

J. M. Schmid and R. H. Frye

Preface

This report summarizes the available literature on the spruce beetle, *Dendroctonus rufipennis* (Kirby) (Coleoptera:Scolytidae), in western North America. While it is primarily concerned with the beetle in the central and southern Rockies, recent work in the northern Rockies and Alaska is also reviewed. However, the information in the report is most applicable to the Rockies and British Columbia, not Alaska.

The literature from the Rockies is mostly derived from research projects in Colorado where spruce beetle research has received increased emphasis since the White River outbreak in the 1940's. Generally, survey reports, biological evaluations, and other unpublished material are not cited except for those that contain a particularly significant finding. Where information was lacking for subjects such as insect predators or impacts on a watershed, it has been derived from other studies. Observations and opinions of the authors have been expressed in certain sections.

The primary purpose of this report is to assemble pertinent information under common binding so that foresters can easily find answers to their questions.

Taxonomy

Before 1963, six species of *Dendroctonus* beetles inhabiting spruce were recognized in North America. The best known spruce beetle in the western United States was *D. engelmanni,* the *Dendroctonus* beetle originally described by Hopkins (1909a) from Engelmann spruce in New Mexico. In 1963, Wood synonymized *D. engelmanni* with *D. rufipennis* (Kirby), *D. similis* LeConte, *D. piceaperda* Hopkins, *D. borealis* Hopkins, and *D. obesus* (Mannerheim). He presented *D. obesus* as the senior name, and thus designated a single species inhabiting a broad geographical area and several species of spruce. However, *D. rufipennis* was an older name which had priority. Wood corrected this oversight in 1969, thereby establishing *D. rufipennis* (Kirby) as the proper name.

These recent name changes have created some confusion among foresters in the central Rockies. Publications referring to *D. engelmanni* prior to 1963 and to *D. obesus* from 1963 to 1969 are relevant for them. From 1969 to the present, articles and reports concerned with *D. rufipennis* are pertinent.

Previous Outbreaks

The tree killing potential of the spruce beetle has been well documented during the last 100 years. On the White River National Forest, Colorado, in the mid-1870's, 10%-25% of the mature spruce were found dead (Sudworth 1900a); while 25%-40% of the mature spruce on the Grand Mesa, Colorado were also dead (Sudworth 1900b). Hopkins (1909b) later confirmed the spruce beetle as the cause of this mortality. These early estimates of the mortality may be slightly exaggerated because they are based on random surveys on horseback. Three years before these Colorado outbreaks, Hopkins reported 90% of the spruce mortality on more than 13,000 acres (5,261 ha) in the White Mountains of the Lincoln National Forest, New Mexico, was attributable to spruce beetles. Between 1916 and 1918, an infestation began on the Aquarius Plateau, Utah, that eventually killed nearly all the large spruce before it subsided in 1928-29 (Mielke 1950).

More recently, the Grand Mesa and White River National Forests, Colorado, have had extensive outbreaks. An infestation in the 1940's killed more than 50% of the merchantable volume of spruce on the Grand Mesa (Struble 1944*)[2]. Simultaneously, the most damaging outbreak in recorded history decimated spruce stands on the White River National Forest (Massey and Wygant 1954). There, the amount of tree mortality was so incredible that a precise estimate of the volume of dead spruce is unavailable, although 3.8 billion board feet (fbm) (23 million m^3) is commonly quoted.

In the last 15 years, an extensive outbreak in British Columbia killed more than 3 billion fbm (18.2 million

[2]*References followed by an asterisk are listed in the unpublished references section.*

m^3), while further north around the Cook Inlet, Alaska, beetles have caused tree mortality on more than 420,000 acres (169,680 ha) (Schmid and Beckwith 1975). At the other extreme of the spruce beetles' range, beetles killed more than 50,000 trees in the White Mountains of the Fort Apache Indian Reservation, Arizona, from 1968 to 1971; more than 15,000 trees on the Santa Fe National Forest, New Mexico, from 1968 to 1971; other, less serious, infestations occurred in Arizona and New Mexico (Lessard 1976). Smaller outbreaks in the early 1970's near Wolf Creek Pass, Colorado and Encampment, Wyo., killed hundreds of spruce (Schmid 1971b). These outbreaks caused the death of many especially large trees near creek bottoms (fig. 1). Other outbreaks in the 1970's on the San Juan and Gunnison National Forests in Colorado and on the Medicine Bow National Forest in Wyoming have caused similar amounts of damage.

Annual mortality attributable to spruce beetles is difficult to determine because, except for outbreaks, much of the mortality originates from single or small groups of trees scattered throughout forests. Wood (1963) estimates one-third to one-half billion fbm (2 to 3 million m^3) are lost annually; the Timber Resources Review (U. S. Department of Agriculture 1958) estimated the 1952 loss at 552 million fbm.

All known major outbreaks have originated from stand disturbances such as blowdown, cull, or right-of-way logging operations (Wygant and Lejeune 1967). Widely scattered blowdown is especially conducive to increases in beetle populations (Wygant and Lejeune 1967) and is a prime source of outbreaks. Over a 3-year period in British Columbia, windfall averaged 1-2 trees per ha on 766 ha (Dyer and Safranyik 1977), so this material would be more than adequate to maintain a population. Logging operations have also started outbreaks (McCambridge and Knight 1972). Where one million fbm (6,061 m^3) or more of mature spruce is harvested for more than three successive years, spruce beetle problems will occur (Hester 1960*), but these may not always develop to outbreak proportions. Problems can originate when much less than one million fbm is cut (Baker 1977*).

Beetle numbers during outbreaks are seldom quantified. One observation during the White River outbreak staggers the imagination but epitomizes the millions of beetles that characterize this incredible outbreak. According to Wygant (1950*), Dr. Lee Yeager observed, in July 1949, a layer of beetles 6 inches (15 cm) deep and 6 feet (1.8 m) or more wide along the eastern shore of Trapper's Lake on the White River National Forest, Colorado (the eastern shore is more than 1 mile (1.6 km) long.



Figure 1.—Extensive tree mortality on the (A) San Juan National Forest, Colorado; (B) White River National Forest, Colorado; (C) land near Tyonek, Alaska.

Hosts

The spruce beetle infests all species of *Picea* in North America. In the southern and central Rockies, Engelmann spruce (*Picea engelmannii* Parry) is the principal host, while blue spruce (*P. pungens* Engelmann) is an infrequent host. White spruce (*P. glauca* (Moench) Voss) and Sitka spruce (*P. sitchensis* (Bongard) Carr) are the principal hosts in Canada and Alaska.

Under outbreak conditions, lodgepole pine (*Pinus contorta* Douglas) has been killed by the spruce beetle during the White River outbreak (Massey and Wygant 1954), and spruce beetles attacked 140 lodgepole pine in north central Colorado in 1957 but did not kill the trees nor produce brood (McCambridge and Knight 1972). Wood (1963) notes that the lodgepole pine beetle (*D. murrayanae* Hopkins) superficially similar to the spruce beetle, caused much of the lodgepole pine mortality attributed to the spruce beetle in the White River outbreak. He has been unable to confirm any of the reports that the spruce beetle was responsible for this mortality (Wood 1977*). However, Massey (1975*) personally examined many infested lodgepole pine, and definitely attributes the mortality to the spruce beetle.

The attack of lodgepole pine by the spruce beetle may be another example of a *Dendroctonus* beetle attacking an atypical host under outbreak conditions when the atypical host is mixed with the common host. The mountain pine beetle (*Dendroctonus ponderosae* Hopkins), a species usually attacking trees in the genus *Pinus,* has attacked white spruce in the Black Hills where individual spruce trees have been occasionally mixed with the predominant host, ponderosa pine *(Pinus ponderosa* Lawson) (Schmid 1965*). Thus, it seems highly probable that other species of *Dendroctonus,* such as the spruce beetle, could attack atypical hosts like lodgepole pine when they are mixed with Engelmann spruce.

Engelmann spruce is widely distributed throughout western North America and is usually found between 9,000-11,000 feet (2,700-3,353 m) elevation in the central Rocky Mountains (U. S. Department of Agriculture 1965). It grows in the coldest and highest forest environment in the Rockies in the United States, characterized by annual temperature extremes of below -40° F (-40° C) in winter and over 80° F (26.7° C) in summer. Annual precipitation exceeds 25 inches (63.5 cm), most of which falls as snow.

Subalpine fir (*Abies lasiocarpa* (Hooker) Nuttall) is a common associate at all elevations in the central Rockies and comprises a variable percentage of the canopy. Lodgepole pine and quaking aspen (*Populus tremuloides* Michaux) are less common associates. Blue spruce is an associate along creek bottoms at lower elevations.

Spruce sawtimber (Engelmann and blue spruce) on commercial forest land in Colorado was estimated to be about 25 billion fbm (152 million m^3) in 1959 (Miller and Choate 1964). Similarly, the volume in New Mexico was estimated to be 3.3 billion fbm (20.1 million m^3) in 1962 (Choate 1966). In 1970, the net volume of Engelmann and blue spruce sawtimber on commercial timberlands was estimated to be 22.3 and 2.7 billion fbm (136 and 16 million m^3) in Colorado and New Mexico respectively (U.S. Department of Agriculture 1973). In 1975, 29 billion fbm (177 million m^3) of sawtimber existed on National Forest lands in Colorado (Cahill 1976*). This sawtimber exists on 2.5 million acres (1,010,000 ha), of which 75% or 1.9 million acres (768,000 ha) is in either a roadless or "reserved" (wilderness, natural area, etc.) category.

The amount of spruce sawtimber cut in Colorado was 106, 131, and 130 million fbm (646,799, and 793 thousand m^3) in fiscal years 1966, 1967, and 1968 respectively (Bailey 1969*). More recently, the volume of Engelmann spruce sawtimber cut in Colorado and Wyoming was 90.7, 98.0, and 60.8 million fbm (553, 598, and 371 thousand m^3) in fiscal year 1973, 1974, and 1975 respectively (Lister 1976*).

Life History and Behavior

Description of Stages

The following descriptions are mostly from Hopkins (1909a), Massey and Wygant (1954), and Wood (1963). More detailed descriptions are also available from these sources.

Egg - oblong, pearly white, 0.75-1 mm in length.

Larva - a white, stout, cylindrical, legless grub, 6-7 mm in length at maturity. Four instars in the larval stage,

Pupa - creamy white, similar in size to the adult.

Adult - dark brown to black with reddish brown elytra; older adults uniformly black. The initial coloration of the adult after transformation from the pupae is white. The adult gradually darkens and thus is white, light brown, and dark brown before becoming mostly black. Adults in the white-to-brown color phase are commonly called callow adults. Length is 4.4-7 mm. Average weight of 50 adults from Green Mountain near Encampment, Wyo., was 16.8 mg. (Schmid 1972*). The compound eye of a spruce beetle contains an average of 272 ommatidia (Chapman 1972).

Life Cycle

The 2-year life cycle as described by Massey and Wygant (1954) is generally common to endemic and outbreak infestations (Knight 1961), although a 1-, 3-, and perhaps 4-year cycle is possible. In the 2-year cycle, adults usually attack in June and July. By mid-October, nearly all of the eggs have hatched and the larvae have developed to the second, possibly fourth, instar. The larvae overwinter, diapausing during the winter before resuming development in the spring. This probably has survival value in very cold climates when severe cold might kill the pupae (Dyer 1970). Sometime during late spring-early summer (about 1 year after attack) the larvae pupate, then transform into adults. The second winter is passed in the adult stage and the following summer they emerge to attack host material.

Beetles can develop from the egg to the adult in less than 1 year when they are inhabiting host material on mountain slopes in a temperature inversion region below 5,000 feet (1,524 m) above sea level in southeastern British Columbia (Dyer 1969). Such slopes commonly develop higher minimum temperatures which accelerate the development during the immature stages. Dyer (1969) assumed the adults would be ready to attack after their 1-year cycle, but he did not follow the adults the next year to determine if this was true.

On warmer sites at lower elevations in the southern and central Rockies, spruce beetles may complete their life cycle in one year, overwintering as new adults and attacking the following summer (Massey and Wygant 1954). In this part of the Rockies, natural stands of Engelmann spruce do not exist at elevations below 8,000 feet (2,438 m), but the more southern latitude may make conditions similar to those Dyer studied. However, it is doubtful if a high proportion of any beetle population in Colorado completes its development and attacks host material within 1 year.

The 3-year cycle is less frequent than the 2-year cycle but more frequent than the 1-year cycle. Massey and Wygant (1954) and Wygant (1959) suggested the 3-year cycle, while Knight (1961) and McCambridge and Knight (1972) documented the conditions contributing to delayed maturation. On a north facing slope in north central Colorado, rate of development was slowed by cold summer weather so that 50% of the beetles in standing trees emerged after 3 years of development and 40% to 57% in felled trees emerged after 3 years (Knight 1961). Similar results were obtained by McCambridge and Knight (1972) in another infestation. In both instances, however, trees were partially infested in successive years; thus the degree of certainty of the 3-year cycle is questionable.

The 4-year cycle, also proposed by McCambridge and Knight (1972), is possible but not yet supported by definitive evidence.

As a general rule, the forest manager should use the 2-year life cycle in management decisions.

Emergence

Emergence of adults has three phases: (1) emergence for hibernation, (2) emergence for attack and construction of egg galleries, and (3) reemergence of parent adults after making an initial attack. The latter two may occur simultaneously.

A varying percentage of adults emerge in August and September for hibernation (see the section on hibernation). These beetles exit their place of development in the phloem on the bole of standing trees and move to the base of the tree where they reenter and overwinter. This behavior apparently helps adults survive since egg galleries are not constructed. From 3% to 88% of the beetles may emerge for hibernation (Knight 1961). Fewer than 50% emerged in 1945, whereas 88% emerged in 1954 (Knight 1961). Beetles in downed material do not emerge for hibernation (McCambridge and Knight 1972).

Emergence for attack and construction of egg galleries usually occurs in June and July in the southern Rockies, but may begin in May. For three consecutive years (1958-1960), emergence began between June 5 and June 20, continued through June and July, and was nearly completed by the end of July (McCambridge and Knight 1972). In British Columbia, flight began in late May (Dyer 1973). In Alaska, beetles emerged in May and June, with peak numbers flying in late May (Beckwith 1972, Beckwith et al. 1977). Since flight does not occur before the maximum temperature in the shade exceeds the approximate flight threshold temperature (about 61°F or 16°C) (Dyer 1973), this explains why emergence varies annually. If air temperatures in the shade exceed the threshold in May, then emergence takes place. However, in the southern Rockies, this normally occurs in June. Both hibernating adults and adults overwintering in place emerge during this period. Adults usually attack host material within a few days after emerging.

Adults emerge and attack host material and then may emerge a second time. The number of reemerging adults is not equally divided between the sexes; males tend to leave earlier and more of them reemerge (Wood 1977*). The number of reemerging adults approaches 100% in standing trees (Massey and Wygant 1954

although only about 20% immediately began a second gallery. In British Columbia, reemergence from pheromone-baited trees was 16% in mid-July, another 18% by early August, and the last 51% between mid-August and mid-September (Lawko and Dyer 1974). However, these trees were pheromone-baited and may not have been attacked under normal conditions; therefore, reemergence may have been abnormal. Furthermore, the percentages represent the percentage of females that reemerged, not the total population. That percentage would be considerably less.

Wood (1977*) notes that many factors appear to influence this habit. It may have been influenced by the severity of resin flow (Lawko and Dyer 1974). Other authorities have speculated that the density of attacks or egg galleries influences the females and causes some to reemerge.

There has also been speculation that this behavior may be a possible explanation for the rapid increase in spruce beetle populations. That is, females could construct a gallery with a complement of eggs, then reemerge, move to another host tree and repeat gallery construction and egg deposition. Each female would thus be constructing two galleries and egg complements so that the population would double, other factors being equal. Data is lacking on whether the reemerging females have completed galleries and laid a full complement of eggs. Data from Lawko and Dyer (1974) suggest that this hypothesis has low probability because, although 18% of the females emerging in late July could fly, the flight muscle in more than 82% of the reemerging beetles had degenerated, making them unable to fly to a new host tree.

Attack Period

Trees may be attacked in May through early August, but if the attack period begins in May, it does not extend into the late summer. In Colorado, attacks began in late June one year and in early July during two other years (Massey and Wygant 1954). Attacks terminated during those years in late July and early August, respectively. McCambridge and Knight (1972) presented an emergence period from early June to late July for three consecutive years which would mean the attack period lasted from early June to early August, depending on the year. Thus, for a specific site, the attack period probably lasts 5 to 6 weeks.

When the attack periods from different sites are considered as one, the attack period may last 3 to 4 months. In exposed logs on the windward side of a small logged area on a south-facing slope in southern Wyoming, attacks were in progress in late May (Schmid 1974*). Approximately 0.75 mile (1.2 km) north of this location, snow depths on a level site in a mature stand exceeded 6 feet (1.8 m) in late May, so beetles did not attack until early July. The difference in the beginning of the attack period is also indirectly substantiated by Chansler (1960) who notes that beetles in a valley flew before those from a site uphill. Since beetle flight and, therefore, attack is dependent on the flight threshold temperature, the duration of the attack period probably reflects the attainment of this threshold under different stand conditions.

Density of Attacks

The density of attacks follows definite patterns depending on the type of host material attacked (standing trees, windthrown trees, trap trees, or logging residuals).

In standing trees, attack densities decrease with increasing height (table 1). The mean number at any specific height differs between infestations, but ranges within definite limits. Attacks have not exceeded a mean value of 10 per square foot (929 cm^2) at breast height where many trees were sampled. Attack densities on the largest diameter trees were not significantly greater than on the smallest diameter trees in aggregation tests in British Columbia (Dyer 1973).

The number of beetles required to successfully attack a standing tree varies with the density of attacks and the bark surface area of the tree. The bark surface area is mainly determined by the diameter and height of the tree. If attacks are held constant in the various

Table 1.—Mean number of attacks per square foot (929 cm^2) of bark surface on standing trees by height.

Massey and Wygant 1954		Knight 1960a		Frye et al. 1977	
Height	Mean	Height	Mean	Height	Mean
1-15	8	0-5	6.6	5	4.2
16-30	5	5-10	5.6	15	2.1
30+	Decreasing	10-15	4.7	25	1.9
		15-20	4.3	35	0.6
		20-25	3.5	45	0
		25-30	3.1		
		30-35	2.7		

zones of the bole, then trees of smaller diameter (7-8 inches or 17-20 cm) at breast height (d.b.h.) receive fewer attacks because of their smaller diameter and short height. In trees 7-14 inches (17-36 cm) d.b.h., the number of beetles absorbed increases primarily because of increases in height. Total attacks on trees greater than 14 inches d.b.h. increase primarily because of increases in tree diameter. Since beetle attacks terminate 40-50 feet (12-15 m) above ground on standing trees, the additional height of these larger trees does not absorb more beetles. When different attack densities are superimposed on different tree sizes, the number of beetles absorbed can show substantial range (table 2).

Two types of unsuccessfully attacked standing trees are infrequently observed in beetle infested areas—pitchouts and strip attacks. Pitchout usually refers to a single unsuccessful beetle attack surrounded by a mass of white pitch. Forest entomologists have broadened its definition to also include those trees exhibiting a large number of pitched-out attacks which have apparently survived the mass attack of the beetles. This has led to some confusion because the word has been used for both meanings without specific definition during its usage. For this report, pitchout and strip attack are defined as follows.

The pitchout is a tree that survives attack densities apparently lethal to other trees. Such trees usually exhibit masses of pitch around the entrance holes to the galleries. The galleries are extremely short, rarely extending more than 1 inch (2.5 cm) in the phloem, and brood is not produced. Pitchouts are rare, observed in fewer than one out of 100 attacked trees.

The strip attack is a tree that sustains attacks on only one side, usually less than one-half the circumference. The number of attacks making up the strip is quite variable, and brood production therein is usually poor. Such trees are more frequently observed than the pitchout and are usually seen on the periphery of a large group of attacked trees or quite distant from other attacked trees when the infestation is somewhat irregular and scattered in the stand.

Strip attacked trees reflect the number of beetles in the attacking population or perhaps a decreasing population. As the attack period ends, only a small number of beetles are left to infest material. If the previously attacked trees are filled with attacks, these beetles must attack uninfested green trees, but there are not enough to attain a uniform density around the circumference. Thus, they attack one side, usually that side that faces the group of infested trees.

Neither pitchout nor strip attack trees die after the attacks. The pitchout does not develop blue stain because the attacks do not penetrate deeply enough or the resinous galleries are unsuitable for fungal growth. The strip attack may develop blue stain in the successful zone of the attack, but the rest of the tree remains unaffected. Pitchouts and strip attacks frequently die in subsequent years because they are infested again by another generation of spruce beetles or other scolytids.

Table 2.—Mean numbers of attacks and beetles to cause mortality in a standing tree of specific d.b.h., based on attack densities from Frye et al. 1977, and Knight 1960a.

D.B.H. (inches)	Frye et al. 1977		Knight 1960a.	
	Number		Number	
	Attacks	Beetles	Attacks	Beetles
7	67	135	111	222
8	97	195	159	317
9	140	280	226	452
10	171	342	282	564
11	204	409	343	685
12	232	463	399	798
13	259	518	463	925
14	276	553	495	989
15	303	607	541	1,082
16	317	635	568	1,135
17	334	669	600	1,199
18	366	732	660	1,319
19	392	784	711	1,422
20	412	823	745	1,489
21	431	862	780	1,559
22	458	916	831	1,662
23	484	968	880	1,760
24	506	1,013	921	1,842
25	530	1,060	965	1,929

In windthrown trees, trap trees, and logging residuals except stumps, attack densities are generally highest on the bottom surface, intermediate on the lateral surfaces, and lowest on the top (tables 3, 4, and 5). The lateral surfaces may have densities greater or equal to those on the bottom surface if the bottom has been damaged or is in contact with the ground. Generally, shading increases the attack density on all surfaces (table 4). Attacks on the upper surface are very scarce (approaching zero) where the bark surface is exposed to the sun. In some cases, *Ips* beetles may attack prior to the spruce beetle and completely occupy the upper surface. Attack densities may also approach zero on the bottom surface if that surface is in contact with the ground.

Table 3.—Low and high mean number of attacks per square foot (929 cm²) of bark surface in windthrown trees.

Surface	Low	High	Range
Top	0.3[a]	0.9[a]	0.6
Lateral	0.7[a]	5.1[a]	4.4
Bottom	1.5[a]	5.9[a]	4.4
All Surfaces	0.8[b]	4.2[b]	3.4

[a] *J. M. Schmid, Unpublished data.*
[b] *Dyer and Taylor 1971*

Table 4.—Mean numbers of attacks per square foot (929 cm²) of bark surface on trap trees. Data from Buffam, Buffam et al., and Lister et al. for the check trees in Silvisar experiments.

Surface	McComb 1953				Nagel et al. 1957		Buffam 1971		Buffam et al. 1973		Lister et al. 1976
	Sunlight		Shaded		Full Sun	Dense Shade	Frilled	No Frill	Ariz.	Colo.	
	Low	High	Low	High							
Top	1.5	8.2	7.0	16.5	1.9	8.7					
Lateral	12.9	17.3	17.6	23.4	11.1	17.8					
Bottom	12.7	16.5	16.0	26.7	12.7	18.4	12.1	9.6	2.6	7.6	6.2

Table 5.—Low and high mean numbers of attacks per square foot (929 cm²) of bark surface on logging residuals.

Dyer and Taylor 1971			Schmid 1977		
Stumps	Mean		Stumps	Mean	
	Low	High		Low	High
Top-shaded	0.9	3.5	Top	2.9	9.3
Bottom-shaded	2.3	5.6	Bottom	2.0	5.4
Logs			**Logs-8'+**		
Top-sun	0.0	0.2	Top	0.3	1.6
Bottom-off ground	0.2	1.0	Lateral	0.5	4.4
Bottom-on ground	2.2	4.5	Bottom	1.2	8.7
			Tops		
			Top	0.4	1.2
			Bottom	1.0	3.4

Attack densities may vary significantly along the length of the bole for any particular surface. McComb (1953) found that attacks varied little along the boles of trap trees, but Schmid (1977) found significant differences in the attack densities within any of the three surfaces of cull logs exceeding 8 feet (2.4 m). Differences along the top surface of exposed material are caused by unequal exposure or shading. Along the bottom surface, densities are significantly different due to ground contact or, in cut logs, dehydration of the inner bark adjacent to the cut surface.

Bark scale length, scale exfoliation (degree of separation from the bark) and bark thickness did not influence attack density on trap trees (Jennings 1959*). However, Jennings found attacks present in bark that ranged in thickness from 0.1 to 0.25 inches (2.5 to 6.4 mm) which may explain why attacks are rare in the extremeties of the bole on downed material.

Attack densities may differ significantly between individual windthrown trees or pieces of logging residual. This also develops because of unequal shading and the size of the attacking population. Unequal shading is frequently caused by the type of windthrow—complete or sporadic toppling of the trees within the stand—or by the logging procedures—felling trees into the uncut forest and piling cull logs or tops.

Attack density is also influenced by the attacking population. Lister et al. (1976) noted that, when the population is large and the number of trap trees (or windthrown trees or logging residuals) is small, the density of attacks is considerably higher than when the opposite conditions exist. Attack densities may also be less variable within and between the infested materials.

Some forest entomologists have hypothesized that some of the variation in attack densities reflects secondary attacks by females. Generally, females probably attack only once. They may create two galleries if they are disturbed during initial gallery construction in the first gallery. They will very rarely attack a tree, construct a gallery and lay a complement of eggs, then emerge and repeat the sequence on another tree. As noted earlier, Lawko and Dyer (1974) showed that more than 80% of the reemerging beetles were unable to fly and thus, could not fly to another tree to begin another gallery. However, there is the possibility that a reemerging female could crawl along the surface of the tree she originally attacked and create a second gallery somewhere else on the tree. While this is a greater possibility, it is also unlikely. The probability that either type of secondary gallery construction could initiate an outbreak is remote.

Egg Galleries and Eggs

Females construct the egg gallery in the phloem with a slight grooving of the xylem (Massey and Wygant 1954). The initial portion of the gallery has a slight crook, but, thereafter, is almost straight and extends upward in standing trees. In downed material, galleries usually extend parallel to the bole. Ventilation holes, when present, are constructed at irregular intervals along the gallery (Wood 1963). As the gallery lengthens, more of the initial portion is packed with frass. Egg galleries in trees injected with silvicides are frequently short, "U", "S", or "Y" shaped (fig. 2) and void of packed frass (Frye and Wygant 1971).

The length of individual galleries varies. Mean length of 218 examined galleries was 5 inches (12.7 cm), while the maximum and minimum were 9 inches (22.9 cm) and 2.5 inches (6.4 cm) respectively (Massey and Wygant 1954). In Utah, average length was 5 inches (13 cm) and maximum length was 9 inches (23 cm) (Wood 1963). Mean gallery length in silvicide injected trees was 1.9 inches (4.8 cm) versus 4.3 inches (10.9 cm) for the untreated trees (Frye and Wygant 1971).

Eggs are deposited in different ways; usually in individual niches or elongate grooves placed on alternate sides of the gallery. Some galleries may have all the eggs in separate niches (Wood 1963). Massey and Wygant (1954) reported eggs were deposited in alternate groups; two to five groups per gallery was common.

The number of eggs per gallery varies. Massey and Wygant (1954) found a maximum number of 144 for 6.1 inches (15.5 cm) of gallery. Average numbers per inch (2.5 cm) of gallery were: 20.5 in standing trees during the White River outbreak (Massey and Wygant 1954), 18.1 in standing trees on the Uncompahgre National Forest, Colorado, and 8.5-9.7 in trap trees on Owl Mountain, Colorado (Knight 1961). Based on these infestations, Knight (1969) proposed that the number of eggs was directly correlated with the stage of the infestation—endemic, epidemic, and declining epidemic infestations producing about 9, 18, and 12 eggs per inch (2.5 cm) of gallery, respectively.

Knight's hypothesis warrants further investigation because Wood (1963) notes that, while the deposition rate in a small infestation in Utah equalled Massey and Wygant's figure of 20.5 eggs per inch (2.5 cm), the rate was maintained only for about one-third the length of the gallery and was confined to the egg deposition area. As the gallery lengthened more of it was unused for deposition, so, the rate decreased. Inspection of the table in Knight (1969) indicates that the mean gallery length was longest where the number of eggs was

A



B



Figure 2.—Egg galleries from (A) natural tree, (B) tree injected with Silvisar 510 prior to attack.

lowest, which supports Wood's statement. Also, it is unclear from Knight's article whether all the data come from standing trees or some may have come from trap trees. The deposition rate in trap trees may be quite different from that in standing trees, thus significantly influencing Knight's hypothesis.

The egg production of nematode infested females may be reduced 40%-70% depending on the species of nematode (Massey 1960*). Nematodes could be a major factor associated with the egg production differences as proposed by Knight (1969).

Egg deposition usually begins less than 1 week after attack, and the eggs incubate 3-4 weeks before hatching (Wood 1963).

Hibernation

Emergence and reentry for hibernation is an idiosyncrasy of the adult spruce beetle in the genus *Dendroctonus*. This behavior is usually exhibited by adults that have not emerged and constructed egg galleries, but Dyer (1973) also found some parent adults hibernating. The habit was first determined by G. R. Struble in 1944 on the Grand Mesa National Forest, Colorado (Massey and Wygant 1954). In the 2-year life cycle in standing trees, a varying percentage of adults emerge during July-September of the second year of development and move to the base of the tree from which they emerged. There each reenters the phloem area by creating its own entrance hole or entering one previously constructed by another adult.

The number or proportion of adults that hibernate varies from year to year; more than 50% may hibernate in some years. Knight (1961) reported as few as 3% and as high as 88% of the adults hibernated on different sites during different years. Densities in the hibernation niche may exceed 300 per square foot (929 cm^2) with more than 10 adults using the same entrance hole (Massey and Wygant 1954).

Spruce beetles do not emerge from trap trees to hibernate (McCambridge and Knight 1972). Based on this finding, it seems improbable that adults would emerge from windthrown trees or logging residuals to hibernate.

Hibernation has a high survival value and may have evolved in response to cold winter temperatures and woodpecker predation. In winter, the basal 6 feet (1.8 m) or more of the bark is covered with snow. The ambient air temperatures above the snowline may be below -40° F (-40° C) (lethal to the beetle) while below the snowline, temperatures are near 32° F (0° C). The snow cover also prohibits woodpeckers from feeding on the brood below the snowline. The combined effect of these factors is higher beetle mortality in the above snowline population. Thus, any beetle leaving the upper bole and hibernating in the basal section has a greater chance of surviving.

Dispersal

Beetles can fly long distances. Flight mill tests indicate a few beetles can fly more than 7 miles (11.3 km) nonstop (Chansler 1960, Shaw 1961). Under field conditions, flight distances may exceed 15 miles (24 km), but it is not known if flight is maintained continuously. As the White River outbreak began to terminate in the Flat Tops country, beetles dispersed from there to near Rabbit Ears Pass, Colorado, a distance of more than 15 miles (24 km) over non-host habitat (Wygant 1976*). Beetles also flew 30 miles (48 km) south from the Flat Tops to establish new infestations south of the Colorado River (Nelson 1954, Wygant 1956, Wygant 1959). While these beetles may have been aided by strong winds aloft, they could have flown a major portion of this distance.

Beetles fly when the air temperature exceeds the flight threshold temperature of about 61° F (16° C) (Dyer 1973). This would account for early beetle activity in open-logged areas where air temperatures are warmer, while emergence and flight occurs later in dense stands.

Beetle populations exhibit considerable variation in flight ability, number of flights, duration of the flight and speed. From 7% to 29% of the population did not fly in flight mill tests (Chansler 1960). Of those that did, 33% were extremely poor fliers (Chansler 1960). Some beetles flew more than 10 times, but 78% flew three times or less. Those beetles that flew three or fewer times, flew for 12-17 minutes during each flight. Those that flew 10 times or more, flew 6 minutes during each flight (Chansler 1960). Some beetles flew continuously for 35 minutes or more. During these flights, the flight speed was high initially, decreased during the first 10 to 20 minutes, and then became constant thereafter (Chansler 1960). Initial speeds averaged 256 feet (78 m) per minute. The presence of internal nematodes did not appear to influence the ability to fly; their effect on speed and endurance could not be determined (Chansler 1960).

The size of the lateralis medius muscle can be used to judge the flight capability (Gray and Dyer 1972). When the average median index of the muscle is within a range of .14-.175 mm, female beetles are capable of flight. Using this index, Lawko and Dyer (1974) found that 82% of the beetles reemerging at certain periods after attacking host material were unable to fly. Those

emerging after August 1 could not disperse to attack additional host material.

Slightly more beetles disperse in an easterly direction than in a westerly direction (Schmid 1970c). This is probably caused by predominantly westerly winds in the spruce-fir country. However, beetles could generally move in one specific direction against predominant winds if an attraction source existed in that direction.

More beetles were recovered at trap trees within one-quarter of a mile, or 20 chains (0.4 km) of the release point than from 1 mile, or 80 chains (1.6 km) (Schmid 1970c). This also indicates that beetles can fly longer distances but will fly only short distances if suitable host material is available.

Under field conditions, the natural dispersal period of the population probably takes place over several weeks, although individual beetles are searching for host material for only several days. Radioactively tagged beetles (Davis and Nagel 1956) dispersed for about 1 week after release (Schmid 1970c). The greatest number of attacks were made 3-5 days after beetle release (Schmid 1970c), which indicates that the majority of the beetles searched and found suitable host material within this period.

Mortality during dispersal is unknown. Passerine birds consume an undetermined percentage of the adults either on the bark or in flight (Baldwin 1969). In studies of the mountain pine beetle in ponderosa pine, birds consumed up to 8.5% (Stallcup 1963). Some forest entomologists believe adult mortality during dispersal may exceed 50%. In view of the low recovery rate (3%-4%) of released beetles derived in dispersal studies (Schmid 1970c), mortality may well exceed that value.

Considerable research effort is needed on dispersal mortality because future tree mortality predictions and trap tree programs are based on estimates of numbers of attacking beetles. We know that the numbers of attacking beetles will be less than the brood estimates derived from our latest samples but we don't know how much less. Thus, our predictions of the number of infested trees or trap trees will be more precise when dispersal mortality is better known.

Sound Production

Sound is produced by both sexes of the spruce beetle. Females produce an infrequent "spontaneous" click by rubbing a sternal file of ridges against a file of ridges along the sutural margin and tip of the left elytron (Rudinsky and Michael 1973). Sounds from gallery constructing females may have an intraspecific spacing function (Rudinsky and Michael 1973). Males produce sound by rubbing together the plectrum (paired conical processes on the median posterior margin of the seventh tergite) and the pars stridens (series of transverse ridges in a file on the undersurface of the elytra near the apex and along the sutural margin) (Michael and Rudinsky 1972). Males produce an audible chirp which may notify the female in the gallery that a male has arrived at the entrance.

Host Relationships

Susceptibility

Susceptibility of standing trees is difficult to define. We can define what trees are more likely to be attacked, but the trees may be attacked because they are more conducive to beetle survival rather than more susceptible. Any standing tree can be killed if enough beetles attack it naturally, but, as noted earlier, large numbers of beetles do not always attack each tree. Nearly all trees naturally subjected to attack densities of 4-6 per square foot (929 cm^2) at breast height, and decreasing vertically thereafter but present to a height of at least 30 feet (9 m), will die. With only strip attacks, or fewer than four attacks per square foot (929 cm^2) at breast height for 10 feet (3 m) or less of the bole, most trees will survive.

The spruce beetle prefers certain host material which may or may not relate to susceptibility. It prefers downed material to standing trees, and the size of the downed tree is less important than the exposure of its bark to sunlight or contact of the bark with the ground. If downed material is unavailable, then standing trees may be attacked. Large diameter standing trees (>20 inches or >51 cm d.b.h.) are preferred to small diameter trees, (6-8 inches or 15-20 cm d.b.h.), but larger trees are preferable if they are relatively free of live branches in the basal section and grow in a competitive stand where natural pruning occurs rather than in an open grown situation without competition and with live limbs in the basal portion.

Susceptibility can be recognized more easily and precisely in stands than in individual standing trees. Knight et al. (1956) outlined the order of susceptibility of spruce stands as follows:

1) Spruce in creek bottoms
2) Better stands of spruce on benches and high ridges
3) Poorer stands on benches and high ridges
4) Mixtures of spruce and lodgepole pine
5) Stands containing all immature spruce

Unmanaged stands can be rated for their susceptibility to potential outbreaks by using the average diameter of the spruce, basal area, species composition and physiographic location (Schmid and Frye 1976). Within these four characteristics, three levels of risk are recognized. Potentially high risk stands usually have an average diameter at breast height over 16 inches (41 cm); basal area of more than 150 square feet per acre (14 m^2 per 0.4 ha); and more than 65% spruce in the canopy and located in a well-drained creek bottom. Low risk stands usually have: an average diameter of less than 12 inches (30 cm); basal area of less than 100 square feet per acre (9 m^2 per 0.4 ha); less than 50% spruce in the canopy; a site index of 40 to 80.

The question frequently arises, "How long is windthrown spruce suitable for beetle infestation?" Unpublished data taken in Rocky Mountain National Park, Colorado, and the Jemez Mountains, Sante Fe National Forest, New Mexico, by Schmid, indicate that windthrow can remain attractive through two attack periods. If a tree remains unattacked during the first possible attack period, then it may be attacked during the second possible attack period, about 1 year later, providing it doesn't unduly desiccate. If it is partially or completely infested during the first possible attack period, then additional infestation is unlikely 1 year later.

Windthrown spruce varies in the duration of its suitability because the windthrow may be the upper portions of trees that have been broken off from the lower bole, or trees partially or totally uprooted. Partially uprooted trees have some root contact with the soil and remain green even though they lie horizontally. Broken off trees and totally uprooted trees lose contact with the soil and die soon after falling. They probably desiccate and become unsuitable faster than partially uprooted trees.

Logging residuals differ from windthrown trees in that the trees have been dismembered and more exposed to direct sunlight. Unless substantially shaded, logging residuals are probably suitable for infestation only during the first possible attack period; thereafter, infestation is unlikely. During the first possible attack period, *Ips* may invade the host material, especially along the top surface, and contribute to the drying process.

Characteristics of Infested Trees

Newly infested standing trees can be distinguished from noninfested trees in a stand by the presence of reddish-brown boring dust in the bark crevices and around the base of the tree—characteristics visible from 10 feet (3 m) or more depending on the amount of frass accumulation. Small, 0.1-inch (.25 cm) frass-clogged entrance holes and occasional open, "ventilation" holes may be visible in the bark. Masses of pitch accumulating around the entrance holes, commonly called pitch tubes, are rare at eye level but are more prevalent on the upper bole where the attacks terminate. The needles on infested trees remain the same color as those on uninfested trees, and few drop during the first summer and fall (Schmid 1976). Needle temperatures of infested trees are the same as those of uninfested trees (Schmid 1976). From an aerial viewpoint, newly infested trees can not be differentiated from uninfested trees during the summer of attack.

Windthrow or logging residuals will not generally show accumulations of frass beneath the tree nor pitch tubes on the bark, but do show frass in the bark on the bottom surfaces.

During the winter months following the summer of attack, woodpecker activity is a good sign of infested trees. Partially debarked trees and accumulations of bark chips around the base can be seen from more than 100 feet (30 m) away, especially against the background of snow, whether on the ground or from the air (fig. 3). The debarked condition and accumulations of bark chips are also visible in succeeding months, but the bark chips on the ground are less noticeable after the snow melts unless the trees are heavily woodpeckered.

Approximately 1 year after beetle attack, clusters of needles die and discolor, turning yellowish-green in the process. Massey and Wygant (1954) reported that the needles on most trees turn this yellowish-green color and fall about one year after attack. More recent evidence suggests that about 30% of the needles on a tree discolor and fall during the summer, which is about 1 year after attack (Schmid 1976). These are the older needles, furthest from the tips of the branches. At the same time, the infested trees may add new growth so that the tips of the branches appear similar to uninfested trees. This partially camouflages the discolored needles and prevents easy aerial detection. Needles that die and discolor do not remain on the tree for months, as do needles from beetle-infested pines, but frequently are removed by winds and rain. Boring dust is less noticeable during this second summer due to dissipation, weathering and coverage by other debris.

As the trees approach the third summer (about 2 years after attack), most of the needles will have discolored making the infested tree appear yellowish-green. The previous loss of needles exposes more branches, giving the tree a grayer appearance. Sometime during this summer, storms strip the remaining needles, and the tree appears as a gray skeleton (Schmid 1976).





Figure 3.—Infested trees may be more noticeable from the air in winter because the bark accumulates around the bases of trees debarked by woodpeckers. Bark around the base of the tree is almost a sure sign the tree is infested by spruce beetles.

Blue Staining Fungi

The spruce beetle transports several species of fungi which develop in the trees the beetle infests (see the section on Deterioration). Some of these fungi impart a blue-gray color to the sapwood (outer xylem), commonly called blue stain. *Leptographium engelmannii* Davidson is the most prominent species consistently associated with the spruce beetle in Engelmann spruce (Davidson 1955). This species was the most common blue stain fungus in trap trees in New Mexico (Hinds and Buffam 1971). *Ceratocystis trunicola* (Davidson) is frequently present in the egg galleries (Davidson 1955). Hinds and Buffam (1971) found *C. olivacea* (Mathiesen) Hunt, and *C. coerulescens* (Munch) Bakshi, in fewer than 10% of their test trees.

Blue stains can completely penetrate the sapwood within a year (Hinds and Buffam 1971). During their development, they occlude the outer conducting tissues in the xylem and essentially stop translocation. This action, plus the destruction of the phloem by the beetles, kills the tree.

The development of blue stain fungi is inhibited in Engelmann spruce by Silvisar 510 (Frye and Wygant 1971). The inhibition is related to dosage—full strength permitted 5% or less of the sapwood volume to be stained, while 30%-35% was stained in the controls when 2 or more weeks elasped between injection and felling (Hinds and Buffam 1971).

Effects of Temperature and Biotic Factors

Temperature

Temperature is one of the most critical factors in the life of the spruce beetle—the extremes are lethal, and the intermediates influence development. Laboratory tests showed that subcortical temperatures of -15° F (-26.1° C) will kill all adults, while -30° F (-34° C) will kill all larvae (Massey and Wygant 1954). Extremely low temperatures in Colorado in 1951 are frequently cited as a major factor in terminating the White River outbreak (Wygant 1956). In the northern Rocky Mountains, an average of 42% of the brood was killed during a cold spell (Terrell 1954). Frye et al. (1974) attributed high larval mortality (88%) in the Fort Apache outbreak to -40° C temperatures in January (fig. 4). At the opposite extreme, temperatures exceeding 130° F (54.5° C) for 30 minutes will kill all



Figure 4.—Below zero temperatures may cause substantial mortality to the larvae; (A) normal larvae, (B) larvae killed by severe cold.

the brood in the bark subjected to such conditions. Temperatures above 110° F (43.5°C) will kill varying percentages of the brood depending on the length of exposure (Mitchell and Schmid 1973).

Temperatures intermediate to these extremes can either accelerate or prolong the normal life cycle. Especially warm temperatures during the summer months (Knight 1961) or temperature inversions on particular slopes (Dyer 1969) can shorten the 2-year life cycle to 1 year. Warmer temperatures cause the larvae to avert diapause and continue development (Dyer 1970). Contrastingly, unusually cold temperatures during the summers can prolong the life cycle to 3 years (Knight 1961, McCambridge and Knight 1972).

The hibernation habit of adults may have evolved in response to cold winter temperatures. When beetles leave the upper bole and reenter the bark near the base, their survival is enhanced because, under normal conditions, 6 feet (1.8 m) or more of snow accumulates on the ground in winter in the spruce-fir forest and covers the bases of the trees. Below this snow line temperatures are near 32° F (0°C), while above the snow line ambient air temperatures exist. Thus, beetles in the bark below the snow line are not subjected to lethal sub-freezing temperatures.



Figure 5.—Woodpeckers are the most important predator.

Woodpeckers

Three species of woodpeckers, the northern three-toed, *Picoides tridactylus* Baird, the hairy, *P. villosus* (Anthony), and the downy, *P. pubescens* (Hartlaub), are important predators of the spruce beetle (Knight 1958) and are listed in decreasing order of importance.

The northern three-toed is most effective because it feeds exclusively on the boles of trees—primarily on trunks of freshly attacked trees rather than old snags (Koplin 1969)—and is indigenous to the spruce-fir habitat (Baldwin 1960). More recently, this species has been observed in the montane zone as well as the subalpine zone (Baldwin 1977*). Its effectiveness is also greater because this species aggregates in infested areas (Koplin 1969).

The hairy woodpecker feeds on the trunks of trees (fig. 5) but examines old snags as well as freshly attacked trees (Koplin 1969). This woodpecker frequents both the montane and subalpine zones (Baldwin 1969).

The downy is the least effective spruce beetle predator of these three woodpeckers. It feeds mainly on the branches of infested trees (Koplin 1969) and has the least pronounced functional response to infestations (Koplin 1972). This species also frequents both the montane and subalpine zones (Baldwin 1969).

The effect of woodpeckers on beetle populations is influenced by the host material, density of beetle brood, and extent of the woodpecker feeding. During outbreak conditions in standing trees, woodpeckers may destroy 55% of the brood (Hutchison 1951), although beetle mortality may vary from 45%-98% (Knight 1958). During low level infestations, woodpeckers may only take about 20% of the brood in standing trees. In trap trees, or downed material, woodpeckers may consume 2%-26% of the brood (Koplin and Baldwin 1970). Although this last citation supports Knight's (1960b) contention that woodpeckers are not effective on beetle populations in downed material, Baldwin (1968) reported a 70%-79% reduction of beetles in windthrown trees. Feeding activity on trap trees or downed material may be influenced by the presence or absence of adjacent, infested, standing trees. When present, feeding activity on the downed material may be reduced. When absent, woodpeckers may concentrate on the downed material.

Feeding activity of woodpeckers fluctuates with the season, day, weather, and infested host material. Feeding on infested standing trees is generally highest during December through March; feeding is greatly reduced on such trees from late May to September

(Koplin and Baldwin 1970). On clear days in winter, feeding begins at daylight, becomes inactive at midday, and resumes in late afternoon (Hutchison 1951, Amman and Baldwin 1960, Baldwin 1960). During winter snowstorms, feeding activity coincides with midday (Hutchison 1951, Amman and Baldwin 1960). In summer, woodpeckers are equally active all day (Koplin 1969). More feeding takes place when the air temperature is below 10°F (-12°C) than when it is above 20°F (-7°C) (Hutchison 1951). In winter, woodpeckers feed predominantly on that part of standing trees above the snow. Snow covering downed trees and the bases of standing trees precludes feeding therein. As the snow recedes in spring, more of the basal section is exposed, but by this time woodpeckers have dispersed. Feeding is commonly limited to seven to eight infested trees until the larvae are no longer available (Hutchison 1951). This creates heavy predation on some trees and relatively light predation on others.

Woodpecker densities per unit area fluctuate with the season and available supply of beetles. During the nesting season, densities may be one pair per 1,000 acres (405 ha) when populations are very low (Baldwin 1969), or six pairs per square mile (259 ha) (Shook and Baldwin 1970), or one pair per 100+ acres (41 ha) in areas of low beetle populations (Baldwin 1968). Peak densities in a vast outbreak (100 square miles or 25,900 ha) appeared to be nine per acre (0.4 ha) (Yeager 1955). This may be the upper limit of woodpecker density during the nesting season because territoriality and antagonistic behavior limits their density.

Woodpecker densities during non-breeding season may reach 30-45 per acre (0.4 ha) when there are numerous infested trees concentrated in a small area (Baldwin 1960). This is due to aggregation through drift, rather than an increase from reproduction (Koplin 1969). At such times, 12 woodpeckers may feed on two adjacent trees (Baldwin 1969).

Beetle larvae may be 99% of the woodpecker's diet in winter but will constitute a lesser amount in summer. Adults (parent and new) may be consumed during winter feeding, but since the larvae are much more numerous, woodpeckers feed mostly on them and rarely confine their feeding exclusively to new adults. Depending on the species, a woodpecker may require at least 1,200-2,200 larvae per day in winter to satisfy its caloric needs when air temperatures are 32°F (0°C) (Koplin 1967). Despite their high energy needs and exclusive feeding on spruce beetles in winter, woodpeckers would be unable to eliminate all the beetles in each tree because some of the beetles hibernate in the base of the tree beneath the protective snow cover. However, woodpeckers indirectly kill some beetles they don't consume by removing the bark and increasing the susceptibility of the beetles to adverse moisture and temperature conditions (fig. 6).

Sapsuckers, *Sphyrapicus thyroideus* (Cassin) and *S. varius* (Linnaeus), and flickers, *Colaptes auratus* (Linnaeus), are associated with beetle infestations (Massey and Wygant 1954, Yeager 1955). They consume mostly vegetable foods and ants (Baldwin 1960) but few spruce beetles. Furthermore, these birds are transients in the spruce-fir forest, present only in summer.

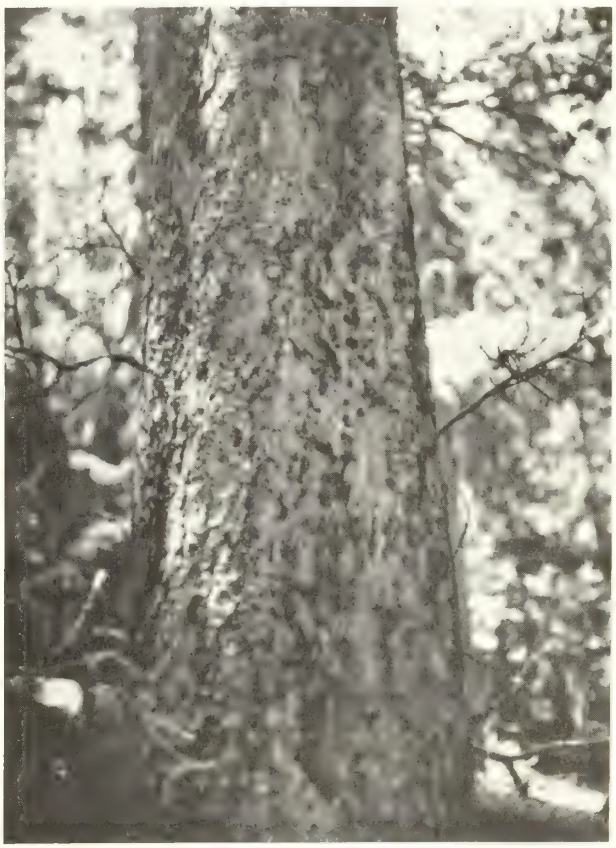


Figure 6.—Woodpeckers debark the infested trees and thus cause substantial mortality as well as providing a means of locating infested trees.

Passerine Birds

The effect of passerine birds (flycatchers, chickadees, etc.) on spruce beetle populations has not been as intensively studied as the woodpecker-beetle relationship. Baldwin (1969) lists the gray-headed junco, *Junco caniceps* (Woodhouse), mountain bluebird, *Sialia currucoides* (Bechstein), and mountain chickadee, *Parus gambeli* Ridgway, as consumers during the flight and dispersal of the beetles. These, plus other less important species, consumed 24%-32%

of the population during one flight period (Baldwin 1969). Passerine birds consumed up to 8.6% of the *D. ponderosae* population during dispersal (Stallcup 1963).

Insect Parasites and Predators

The effects of insect parasites and predators on spruce beetle populations are quite variable. These agents are a tremendous mortality factor in some infestations, perhaps accounting for more than 60% of the beetle deaths. In other cases, the entomophagous species kill a large number of spruce beetles, but their effect on the population is minimal. Some forest entomologists believe insect parasites and predators are primarily responsible for keeping beetle populations at endemic levels. However, the fact remains that infestations develop from a low level to outbreak status with these organisms present. Furthermore, under outbreak conditions, these organisms seldom cause a rapid reduction of the beetle population to preoutbreak levels, even though they may kill a large number of beetles. Based on this, it is difficult to conclude that natural populations of these insect parasites and predators regulate spruce beetle populations.

Generally, the important parasitic and predacious species are known (Massey and Wygant 1954, Jensen 1967). The life cycles, habits, and mortality effects of some species are known either from studies of the spruce beetle or studies on other *Dendroctonus* beetles. Other species are relatively unknown. Some are thought to be predacious or parasitic because they are related to other species that are.



Figure 7. —*Coeloides* **wasp ovipositing in the bark. These wasps are the most important parasites.**

Insect Parasites. *Coeloides dendroctoni* (Cushman) (Hymenoptera:Braconidae) is a solitary parasite with a life cycle of 9-12 months (Ostmark and Knight 1960*). The larval stage externally feeds on the third and fourth instars of the spruce beetle. The female wasp oviposits an egg on or near the larva through the bark (fig. 7). Peak oviposition is in July. The egg hatches in 1 to 4 days. The larval period is very short, less than 1 month in the laboratory. The larva feeds on the host, draining internal fluids and detaching itself when the host larva is almost dry. The parasite commonly spins a white or tan cocoon in which it overwinters. The adult chews through the cocoon and bark; some emerge in late May, but this is probably as variable as spruce beetle emergence. Males usually emerge before females and copulate with them upon their emergence. Adults live 8-15 days in the laboratory without food, slightly longer if supplied a sugary water solution. Females search for host larvae immediately after emergence and seem to prefer late instar larvae. *Coeloides* larvae are not generally found in infested trees until about 1 year after they are attacked. The number of *C. dendroctoni* per square foot (929 cm^2) of bark ranged from 0.1 to 2.6. The percentage of brood that is parasitized varied by the status of the infestation—1.7 to 11.3 in static and increasing infestation, 0-60 in decreasing infestations. *Coeloides* is commonly absent in trees that have been heavily woodpeckered.

Roptrocerus eccoptogastri Ratzeburg (Hymenoptera:Pteromalidae) adults have been found from May to late August. They are rarely observed in the air or on the bark of infested trees because they are usually within the egg galleries of the spruce beetle, presumably searching for host larvae. No males have been observed, so, the species may be parthenogenetic. In the laboratory, females produced from one to three eggs. Oviposition and eggs have not been observed on beetle larvae, but first instar *R. eccoptogastri* larvae feed externally on the third and fourth instars. They pupate inside the shriveled exoskeleton of the larva and do not form a cocoon. The life cycle is completed in less than 20 days. The numbers of host larvae consumed and densities of the parasite have not been determined.

Cecidostiba burkei Crawford (Hymenoptera: Pteromalidae) is parasitic only on the beetle larvae (Massey and Wygant 1954) but may also be parasitic on insects associated with the spruce beetle. Oviposition habits are thought to be similar to

Coeloides dendroctoni. Adults have been abundant in some locations. Life history and habits of this insect are not well understood.

Insect Predators. *Medetera aldrichii* Wheeler (Diptera: Dolichopodidae) is the second most important biological mortality agent of the beetle; the first is woodpeckers. Its effectiveness may be lessened by indiscriminate feeding habits—larvae feed on the immature states of associated insects (Massey and Wygant 1954). Adults glide over the bark surface, females constantly probing the bark crevices. The eggs are laid in the egg galleries of the spruce beetle (Massey and Wygant 1954). However, on *D. ponderosae* infested trees, *M. aldrichii* eggs were found in degenerate resin ducts (minute depressions) in the bark (Schmid 1970a). The larvae then crawled from these sites to the gallery entrance or another gallery opening to enter (Schmid 1971a). Once in the gallery, the larvae fed on the eggs of *D. ponderosae* and then later on the larvae. *M. aldrichii* pupated in the old phloem. This species accounted for a large portion of the initial mortality to *D. ponderosae,* but its effect on the spruce beetle remains to be determined.

Thanasimus undatulus Say (Coleoptera:Cleridae) adults were active in small numbers in July and August. This clerid is aggregated to living spruce trees by frontalin (Dyer 1973, Dyer 1975) and probably by other pheromones of the spruce beetle. The adults killed a conservatively estimated 3-4% of the adult spruce beetles attacking trees in British Columbia (Dyer et al. 1975). How many spruce beetles they consume in the southern Rockies is unknown. Since they are not abundant, their effect is probably minimal. In Colorado, this species may be primarily predacious on other small scolytids associated with the spruce beetle. Adults consumed an average of one adult *Dendroctonus pseudotsugae* Hopkins per day. Females can produce more than 300 eggs in 7 months in the laboratory (Cowan and Nagel 1965). Eggs hatch in 6-8 days, and the larval stage has three instars. First instar *T. undatulus* larvae feed on first instar spruce beetles. Later instar *T. undatulus* larvae feed on the later larval stages and pupae of the beetle. The larvae apparently overwinter, pupate in spring, and emerge in early summer.

Enoclerus lecontei Wolcott (Coleoptera:Cleridae) adults prey on adult spruce beetles during their emergence and attack period. Adults are active during the summer months. Females lay up to 115 eggs (Cowan and Nagel 1965), probably in the bark. The larvae feed on the larvae and pupae of the spruce beetle. The effect of this species on the adult and larval populations of the beetle is unknown.

Enoclerus sphegeus Fabricius (Coleoptera:Cleridae) adults were most abundant in August and still present in September (Jensen 1967). With other species of *Dendroctonus,* adults are present from May through October. Adults may consume an average of 1.7 *D. pseudotsugae* adults (Cowan and Nagel 1965) or 0.8 *D. ponderosae* adults (Schmid 1970b) per day. On *D. ponderosae* infested trees, adults are constantly moving over the bark. Females apparently lay their eggs in the bark. The larvae make their way into the galleries and prey on the larvae and pupae of the spruce beetle. The clerid larvae consumed an average of 25 *D. ponderosae* immatures during development (Schmid 1970b), so, it is probable that they consume a like number of spruce beetles. The total effect of adult and larval predation on the spruce beetle remains to be determined.

Additional dipterous predators *Erinna abdominalis* Loew, *Zabrachia polita* Coq., *Lonchaea coloradensis* Mall., are found in Massey and Wygant's (1954) extensive list of insects associated with the spruce beetle, but their importance is unknown.

Corticeus parallelus Melsheimer (Celeoptera: Tenebrionidae) is generally regarded as a phytophagous species in both the larval and adult stages. Jensen (1967) observed it eating spruce beetle eggs when they were encountered in its normal feeding on partially decomposed debris in the egg gallery.

Rhizophagus dimidiatus (Mann.) (Coleoptera: Rhizophagidae) is an abundant coleopterous associate of the spruce beetle. Most closely related species are fungus feeders. Massey and Wygant (1954) suggested this species might be predacious. It probably feeds similarly to *C. parallelus* and so can not be called a true predator. Most rhizophagids might be classified thusly.

Mites

Mites from the families Acaridae, Ascaidae, Eremaeidae and Phytoseiidae were associated with the spruce beetle on the Uncompahgre National Forest, Colorado (Sluss 1955). Sluss suggested that some of these species were predacious on the beetle but did not verify this. He believed other species were just associated with the bark or frass and were not detrimental to beetle survival.

Boss and Thatcher (1970) found only *Erynetoides sculutis* Hunter, a nonpredacious mite, associated with spruce beetles from three sites in Colorado. No predacious mites were found feeding on any stage. Boss and Thatcher thought that the mites used adults only for dissemination and did not feed on the immature stages because the tightly packed frass in the galleries

prevented access. Frass mixed with oleoresin could easily prevent mites from reaching the immature stages, but dry frass alone would probably have enough spaces to permit mite passage unless it was exceptionally densely packed.

Nematodes

Four species of nematodes, *Sphaerulariopsis dendroctoni* Massey, *Contortylenchus reversus* (Thorne), *Ektaphelenchus obtusus* Massey, and *Parasitorhabditis obtusa* (Fuchs), are endoparasites of various stages of the spruce beetle (Massey 1956).

S. dendroctoni infests both sexes of the beetle equally (Massey 1956) and may reduce oviposition of infested females by 70% (Massey 1960*). Individual trees may have as high as 75% of the beetles infested with this nematode, although a group of trees may have only 35% of the beetles infested. Male beetles help disseminate this nematode (Massey 1956).

C. reversus parasitizes the larval, pupal, and adult stages of the spruce beetle. Egg production of infested female beetles may be reduced 45% (Massey 1960*). Individual trees may have 36% of the beetles infested with *C. reversus,* but the percent of nematode-infested beetles is generally lower (maximum 23%) for a group of trees.

The effect of *E. obtusus* and *P. obtusa* on the beetle is unknown. Both have been collected from several locations in the beetles' range.

Mikoletzkya pinicola (Thorne) is an ectoparasite and is found beneath the elytra of the spruce beetle (Massey 1956). Its biology and effect are also unknown.

Several other nematode species are associated with the egg and larval galleries of the spruce beetle (Massey 1960*) but apparently do not parasitize the beetle.

Nematodes may cause the rapid decline of localized beetle infestations (Massey 1968*)—they contributed significantly to the decline of a small outbreak (McCambridge and Knight 1972). Since they seem to be one of the first indicators of the decline of an infestation, they may be worthy of study as a predictor of population trend.

Associated Scolytids

Many species of scolytids inhabit the spruce trees infested by the spruce beetle. Most of these enter the trees only after they have been attacked by the beetle (Massey and Wygant 1954), but these host trees are live and standing. A few scolytids enter downed material (usually dead) before the spruce beetle.

The most common associates are in the genus *Ips*.[3] In New Mexico and southern Colorado, *I. pilifrons sulcifrons* Wood is the common *Ips* associate; in northern Colorado, *I. pilifrons pilifrons* Swaine; in western Colorado, Utah, western Wyoming, and northern Arizona, *I. pilifrons utahensis* Wood, *I. hunteri* Swaine is an associate in blue spruce, but is also common in Engelmann spruce in Colorado and Utah. *I. perturbatus* (Eichoff) is the important species in Canada and Alaska. Along the Pacific coast, *I. tridens tridens* (Mannerheim) cohabits with the spruce beetle, while further inland from Alaska to northwestern Wyoming, *I. tridens engelmanni* Swaine is an associate. Also, in Alaska and Canada, *I. borealis borealis* Swaine is found with the spruce beetle.

Ips beetles frequently infest the upper portion of downed material, sometimes before the spruce beetle, sometimes after. Their galleries are often quite numerous, and the larvae develop rapidly so that these species seem to completely mine the phloem (fig. 8).

[3]*Dr. Stephen Wood kindly provided the following information on the distribution of the species of* Ips *and, later in this section, information on the other scolytids.*



Figure 8.—*Ips* beetles commonly infest the upper surfaces of downed material, especially those surfaces directly exposed to the sun.

The upper surface of tops and cull logs in logging areas are frequently riddled. Competition between these species of *Ips* and the spruce beetle has been suggested as a limiting factor to spruce beetle populations. Competition may be important in shaded host material and in the lateral surfaces of exposed host material; otherwise, it does not seem to be a factor. Since the spruce beetle prefers shaded material and avoids fully illuminated logs, while the *Ips* species prefer the exposed material, these preferences preclude most competition. The importance of competition is yet to be determined.

Lesser known scolytids but equally abundant in some cases are species of *Polygraphus, Scierus, Dryocoetes* and *Pityophthorus*. *Polygraphus rufipennis* (Kirby) is almost as important as *Ips* and is capable of killing small, stressed trees up to about 10 inches (25.4 cm) d.b.h. *Scierus annectans* LeConte, *Dryocoetes affaber* (Mannerheim) and *D. autographus* (Ratzeburg) are found in butts and stumps. Three species of *Pityophthorus* (*nitidulus* (Mannerheim), *occidentalis* Blackman, *bassetti* Blackman) are found in the branches of spruce beetle-infested trees.

Effects of Infestation

A spruce beetle infestation has immediate and long-term effects on the spruce-fir stand. The immediate effect changes the stand structure and composition. The long-term effect comes from successional changes in the stand caused by the death of the spruce as well as the associated effects on water yield, forage production, wildlife populations, and fire hazard.

Stand Structure and Composition

Stand structure is modified by spruce beetles. They reduce the average age of the surviving trees, lower the average diameter and height of the stand and the spruce component, lower the density, and leave suppressed and intermediate trees as the dominant or co-dominant spruce (fig. 9).

The number of live trees may be drastically reduced—from less than 1 per acre to 99% of the trees over 10 inches (25.4 cm) d.b.h. During the White River outbreak, 99% of the overstory trees were killed throughout thousands of acres. Despite this, scattered, single, medium diameter trees survived within the devastated stand. In Alaska, mortality of white spruce more than 5.0 inches (12.7 cm) in diameter exceeded 90% on some sites but generally averaged 65% over 70,000 acres (Baker and Kemperman 1974). In Arizona, about 5% of the trees over 5.0 inches (12.7 cm) d.b.h. were killed (Frye and Flake 1971). However, a greater percentage of the larger trees died than



Figure 9.—This dead stand on the White River Nat. For., Colo., exemplifies typical mortality to the dominant trees during an outbreak.

did the more numerous intermediate-sized trees. Tree losses were highest in areas with the largest trees and highest basal area (Frye and Flake 1971).

The number of seedlings and saplings is not immediately affected unless the infestation is logged. Without logging, an insignificant few will be killed or injured in subsequent years by the falling of the dead overstory. Generally, the existing seedlings survive better after the overstory trees are killed. Existing seedlings will compete with herbaceous vegetation; this competition will become more intense in 2 or more years after the death of the overstory trees, when the herbaceous vegetation has had time to also respond to the change in conditions.

Seedlings may become established in the first three years after the trees are killed but then be unable to survive competition from the dense herbaceous vegetation which also develops.

With logging, established seedlings can be reduced in number to well below the minimum level for adequate stocking (300 per acre or 0.4 ha) but this varies with the intensity of the logging. If logging has re-

duced the number of seedlings below the adequate level, then planting may be desirable. Spruce seedlings may need partial shade (Ronco 1961). Full light intensity impairs their physiological functioning and causes high mortality (Ronco 1961). Drought and frost heaving are not important mortality factors to planted spruce seedlings (Ronco 1961).

Species composition can be altered. In Colorado, stands which were 90% spruce-10% fir in the overstory before the outbreak became 20% spruce-80% fir after the White River outbreak (Schmid and Hinds 1974). In Alaska the white spruce-paper birch (*Betula papyrifera* Marsh) ratio changed from 77%-22% to 55%-45% respectively (Baker and Kemperman 1974). Most infestations cause compositional changes over a less extensive area than the two previous examples, but they can be just as intensive in a small area, so, the species composition within a portion of a stand may drastically change even though the overall composition of the stand is only slightly altered.

There are immediate and long term effects of infestations on species composition of seedlings. Existing spruce seedlings benefit more from the opening of the stand than do fir seedlings. Immediate composition will remain unchanged. Subsequent composition depends on the intensity and extent of the outbreak.

Succession

The characteristics of potential outbreak stands and the changes in species composition caused by beetle infestations provide a basis for speculating on ecological succession in the spruce-fir type (Schmid and Hinds 1974). Daubenmire (1943) classified spruce-fir as the climatic climax. Alexander (1974*) predicts that spruce is the climax species in the central Rockies, and will eventually replace the fir if the stand is not disturbed. Miller (1970) correlated age structure in spruce-fir stands in the central Rocky Mountains with spruce beetle outbreaks, but did not speculate on stand succession. Schmid and Hinds (1974) agreed with Miller, but further suggested that the combined forces of spruce beetles, and *Dryocoetes confusus* Swaine and associated fungi alter the status of the spruce and fir components over the years, first toward fir, then toward spruce, and then back to fir as each species matures and spruce beetles periodically reach outbreak status.

The development of a spruce-fir forest over several centuries might be as follows: Assume a stand like one of those on the White River National Forest after the beetle outbreak in the 1940's; 80% fir-20% spruce in trees larger than 3 inches (7.6 cm) d.b.h., and the same or a higher percentage of fir in the seedling class. Both species grow rapidly. Fir continues to predominate and slightly increases its component in the overstory. As the overstory firs reach a diameter of 16 to18 inches (40.6-45.7 cm) d.b.h., or 125 to 175 years, they begin to die and fall out of the overstory. Why fir dies is not completely understood, but Swaine (1933) cites *D. confusus* Swaine as a mortality agent in British Columbia, and Molnar (1965) identified a *D. confusus*-fungus complex as killing 6- to 15-inch (15-38 cm) fir. The total BA curve reflects these decreases due to the loss of fir (fig. 10). Younger spruce and fir use these unoccupied sites and increase in size, but the spruce component in the overstory increases proportionately more than the fir.

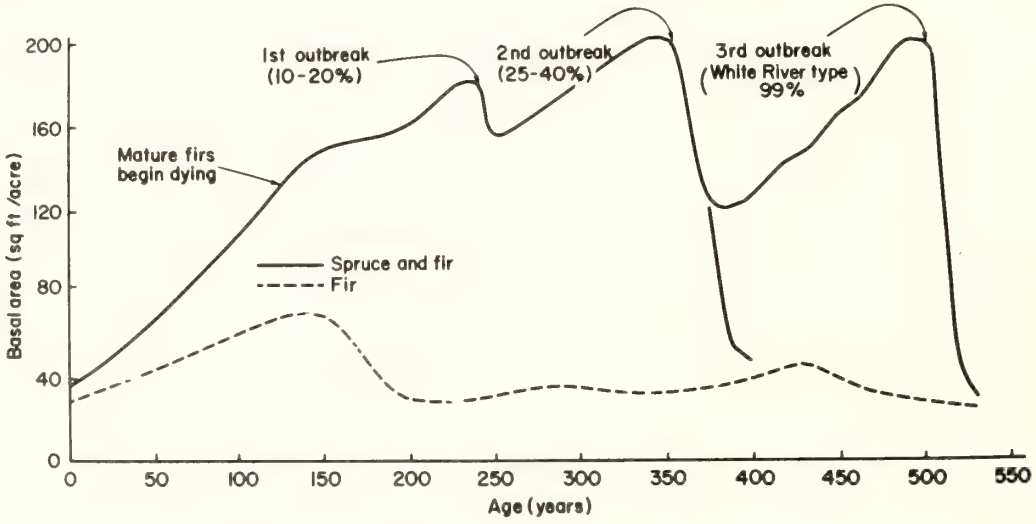


Figure 10.—Hypothetical curve of succession in the spruce-fir forest using basal area as an indicator of stand structure.

Meanwhile, more seedlings are becoming established, so, the spruce component is increasing slightly because of two factors. First, even though fir seedlings vastly outnumber spruce seedlings, the original removal of the canopy by the beetles favors the less tolerant spruce more than it does the highly tolerant fir. This allows spruce seedlings to compete more vigorously with fir, whereas, prior to the outbreak, fir was in the more advantageous position. Second, animals or other factors heavily damage more fir seedling leaders than spruce leaders, so spruce gains valuable height on fir. Eventually, since spruce lives longer and grows larger (LeBarron and Jemison 1953), it becomes dominant. At that point, the fir occupies a smaller percentage of the canopy.

Total BA begins to increase rapidly and proceeds toward the potential of the site as the maturing spruce grow. At periodic intervals spruce beetle outbreaks reduce the total BA and the spruce component, as Miller (1970) suggests, but the initial outbreaks kill less than 50% of the spruce—probably 10% to 20% (Frye and Flake 1971), or 25% to 40% (Sudworth 1900b) —before the beetle population subsides because of natural factors.

Such outbreaks are probably examples of the "pocket biology" of the spruce beetle—a situation where the beetles reach outbreak status in a generally immature stand with pockets of larger diameter trees. The spruce component decreases and fir increases, but the spruce still occupies more than 50% of the live BA. As the stand recovers after each outbreak, the stand tends more toward a single story. The stand continues to grow and approaches maximum BA. It is then highly susceptible to spruce beetle outbreaks. Eventually, given the moisture and wind conditions characteristic in the central Rockies, blowdown occurs. Spruce beetles develop to outbreak proportions in the downed material, and attack the surrounding standing spruce, killing it so that the stand becomes fir, and the transition from predominantly fir to spruce to fir is complete.

The trend of the total BA curve after the stand reaches the site potential and sustains an outbreak is open to further investigation. It may proceed in a wavelike trend resulting from intensive outbreaks, continue downward from an expanding initial infestation, or remain relatively static with minor fluctuations due to endemic infestations. Historical data and knowledge of spruce-fir stands suggest the wavelike trend is probably the most likely.

Watershed Relationships

The effects of outbreaks relate to streamflow, interception, and transpiration. Love (1955) estimated that streamflow increased more than 2 inches (about 22%) annually for the entire watershed, or a 7.7-inch depth (about 75%) for the 226 square miles (58,534 ha) of beetle-killed spruce in the latter years of the White River outbreak. He attributed this increase to reduced interception and transpiration. The dead trees permitted a greater accumulation of snow on the forest floor which, in turn, yielded more streamflow because the dead trees did not evapotranspire (Love 1955).

Bue et al. (1955) discount the effect of the White River outbreak, and indicate that some factor(s) not associated with the death of the trees was responsible for the change in streamflow. Mitchell and Love (1973) reanalyzed the White River data and concluded that there was a significant increase in annual flow, 1.6 to 1.9 inches (about 16% for the entire watershed, or 5.5 to 6.4 inches (about 58% from the beetle-damaged area)) although the increase was less than Love's 1955 analysis estimated. Bethlahmy (1975) also concluded that the most logical explanation for the increase in water yield relates to changes in vegetation cover, i.e., the vast mortality of the overstory spruce.

The effect of an outbreak is probably similar to the general changes that occur after logging, with minor differences caused by the standing dead trees. Leaf and Alexander (1975) noted that total snow storage was not changed but was distributed differently following harvesting. More snow (+30%) accumulated in the logged areas while less snow (-20%) accumulated in the uncut forest. The length of the snowmelt season remained the same, but snowmelt increased in the early part of the season and decreased in the latter part. Peak streamflows will not increase appreciably when 40% of the watershed is patch cut. Evaporation is greater from the snowpacks in the logged areas than from the uncut forest. Evapotranspiration and interception losses were reduced in proportion to amount of forest cover removed. Water yields were highest where the openings were kept to less than eight tree heights in diameter. On a watershed basis, the redistribution of snow into clearings increases runoff because less water is needed to satisfy soil moisture deficits due to reduced transpiration loss after tree removal. The increase in water yield will last for 30 years or longer depending on how soon the forest cover density reaches its maximum value.

How similar an infested area is to a harvested watershed depends on the extent and intensity of the infestation. Assuming the area affected by an outbreak approaches the size of the cut area discussed in Leaf and Alexander (1975), then the following appear logical: (1) snow deposition among dead trees should be slightly less than in a clearcut opening because the dead trees will intercept some snow and prevent it from accumulating on the ground; interception will decrease

as the branches weather and drop to the ground; (2) evapotranspiration should be the same as that of the cut areas, while interception loss should be slightly greater; (3) standing dead trees should inhibit winds from scouring out the snow, so, the size of an infested area should not be a factor; (4) the snowmelt season should begin somewhat later than that of clearcut areas because the dead trees will provide some shade; (5) the pattern of streamflow should correspond closely to the pattern of the cut area; (6) water yields should be slightly less than in cut areas because of the slightly greater interception loss; (7) the increase in water yield should last as long as it would in selectively cut stands; (8) soil erosion should be negligible.

Forage Production

Relatively little forage is found in mature spruce-fir forests (Yeager and Riordan 1953). In green stands, mature spruce and fir dominate all other vegetation, using a large portion of the available light, moisture, and soil nutrients (Yeager and Riordan 1953). Stands on dry slopes are more or less brushless, while those on moist sites have varying densities of undergrowth. Under a spruce-fir canopy, the predominate ground cover in green forests is whortleberry *(Vaccinium).* On dry sites, a shrubby buffaloberry *(Shepherdia),* and scattered composites, *Arnica* and *Aster,* are present. On moist sites, mountain bluebells *(Mertensia),* larkspur *(Delphinium),* and butterweed *(Senecio),* are common, while wild currants *(Ribes)* and elder *(Sambucus)* are common shrubs.

Comparing green stands to beetle-killed stands, grasses and sedges showed increased density in dead stands (Yeager and Riordan 1953). Forbs were 2.3 times more numerous in dead stands, while browse (woody) plants showed a steady, unexplainable decrease. The greatest density, number of species, and index of occurrence of plants was in beetle-killed stands (Yeager and Riordan 1953).

How long forage population will continue to increase after an outbreak has not been determined. Under outbreak conditions like the White River, it should increase each year for several years and reach maximum production in 3-5 years (Currie 1977*). Annual production would then fluctuate around this maximum level until the spruce and fir seedlings begin to compete. If the site is occupied with advanced regeneration, it should begin competing in 50 years. If the site is relatively unoccupied with advance regeneration, forage production may be unaffected for considerably more than 50 years, which may preclude the establishment of seedlings.

Forage production in beetle killed stands is probably similar to that of logged areas. Wallmo et al. (1972) found 853 ovendry pounds per acre (388 kg per 0.4 ha) on cut strips versus 391 pounds per acre (178 kg per 0.4 ha) on uncut strips, 16-18 years after cutting. In terms of deer forage, 509 pounds per acre (231 kg per 0.4 ha) were present on cut strips, and 346 pounds per acre (157 kg per ha) on uncut strips (Wallmo et al. 1972). They also estimated that forage supplies were 47% greater on the cut strips.

Wildlife

The effects on each species depends on that species' requirements and the intensity and extensiveness of the infestation. Where only a few trees are infested on 1-2 acres (< 1 ha), the changes would be insignificant. Where the outbreak reaches the intensity and extensiveness of the White River outbreak, then significant changes would be expected. Most of the following information relates to major outbreaks. Since trends in mammal and bird populations have not been adequately studied, such expected changes are opinions based on knowledge of the animals' requirements.

Elk *(Cervus elaphus* Linnaeus), and deer *(Odocoileus hemionus* (Rafinesque)), benefit from beetle outbreaks because forage production increases. Wallmo (1969) notes that deer use was significantly higher in logged strips than in adjacent uncut forests 10 years after cutting. This is a response to increased forage on the cut area—a condition also to be expected beneath an infested stand. Although summer range is not critical for elk and deer in Colorado, the increased abundance and diversity of their forage in a large beetle-killed area could result in greater accumulations of body fat, and thus better enabling them to survive on their critical winter range which is below the spruce-fir habitat.

Red squirrels (*Tamiasciurus hudsonicus* (Erxleben)), were adversely affected because of the loss of spruce seed (Yeager and Riordan 1953). Chipmunks *(Eutamias* spp.), and meadow mice (*Microtus* spp.), increased appreciably, presumably because of the increase in grasses and forbs (Yeager and Riordan 1953). Although white-footed mice (probably deer mouse *Peromyscus maniculatus* (Wagner)), and boreal redbacked mice (voles) *Clethrionomys gapperi* (Vigors), decreased and increased respectively, these changes were independent of the beetle outbreak and probably reflected cyclic changes (Yeager and Riordan 1953). Other small mammals were either unaffected or the data was insufficient to detect an effect.

Since meadow voles (*Microtus pennsylvanicus* (Ord)), and redbacked voles are the most important food of the pine marten *(Martes americana* (Turton)), and they increased, then pine marten should increase.

However, marten prefer densely stocked stands of subalpine fir (Koehler et al. 1975), so, loss of canopy cover is detrimental. Also, marten activity is greatest in stands with less than 30% canopy cover when snow depth is less than 12 inches (30 cm) (Koehler et al. 1975). Snow accumulates to several times this depth in green spruce-fir and even greater depth in beetle-killed stands (see Watershed section). This would limit marten usage. Thus, the increase in food may have been counterbalanced by the loss of cover leaving marten populations about the same.

Snowshoe hares (*Lepus americanus* Erxleben) showed no response to the White River outbreak (Yeager and Riordan 1953). Coyotes, (*Canis latrans* Say), a predator of rabbits, were not observed.

Woodpecker populations initially would benefit from a large outbreak and increase due to the increase in spruce beetles. After an outbreak subsides, woodpeckers would still benefit from the large numbers of secondary insects (cerambycids, ants, other scolytids) present, but this would only last 2-3 years. After these insects decline, woodpecker populations would decline because of the lack of food. Even though more nesting sites would be available in the snags, the lack of food counterbalances this benefit.

Other insectivorous species such as nuthatches *(Sitta* spp.), and brown creepers (*Certhia familiaris* Linnaeus) would be similarly affected. Initially they benefit even though the spruce beetle is not their primary food, but, as the needles and bark fall off, available food and cover would be greatly reduced so their numbers would decline.

Pine grosbeaks *(Pinicola enucleator* (Linnaeus)) were adversely affected because of the loss of spruce seed (Yeager and Riordan 1953). Spruce grouse *(Canachites canadensis* (Linnaeus)) would also decline because of the loss of cover and winter food (spruce buds).

Owls and hawks would not be affected in the first years (1-2) after an outbreak but would increase in later years due to the increase in mice populations and to a lesser extent, nesting sites.

The Gray jay (*Perisoreus canadensis* (Linnaeus)) appeared unaffected (Yeager and Riordan 1953).

Fire Hazard

The importance of the fire hazard in a beetle-killed spruce-fir stand has been exaggerated and is less than for other beetle-killed timber types, especially the pine. Miller (1970) noted that evidence of widespread fires between 1750 and 1930 is lacking on the White River Plateau. One large fire in 1879 was started by Indians. Mielke (1950) stated that no large fires have burned in the spruce-fir in Colorado since 1900. Since the White River Outbreak, the only fire of significance (started by elk hunters) burned 4,500 acres (1,821 ha) in 1975 in the beetle-kill area. Based on this evidence, Watt's testimony that, if the spruce beetle was not controlled, a very serious fire hazard would be created on the White River Plateau (U.S. Senate 1952) exaggerates the danger.

Unquestionably, spruce beetle outbreaks create a large fuel source, and the snags are potential lightning rods. Cahill (1977) estimated that more than 40% of his study area in the White River outbreak area had 55 or more tons of dead fuel per acre (49,895 kg per 0.4 ha), and 97% of the forested area had 55 snags per acre (0.4 ha)—this some 30 years after the outbreak. However, most storms are accompanied by rainfall which dampens the vegetation and prevents development of a widespread fire. Also, frequent showers during the fire season create a moister environment—one reason why spruce grows there. Thus, the hazards seem to be negated by the moister conditions.

Deterioration

Beetle-killed spruce fall at a slow rate. Mielke (1950) found 84% still standing after about 25 years—rate of fall was 0.7% per year. Schmid and Hinds (1974) found an average rate of 1.5% per year for the White River outbreak and 1.3% per year on the Aquarius Plateau (Mielke's study area). The rate of fall seems to increase slightly with time.

Trees fall mainly because of root and basal rots. Both are equally important. Windthrow was not important in the infestation on the Aquarius Plateau (Mielke 1950), but it accounted for 25% of the trees in the White River outbreak area after 20 years (Hinds et al. 1965).

Although Mielke (1950) rarely found decay 1-2 feet (.3-.6 m) above ground, it can still be present. Three years after being infested, the moisture content of the heartwood and sapwood of standing trees was generally below 22%, so, trunk decay fungi were unable to develop (Mielke 1950). However, trunk decay fungi can develop where there is sufficient moisture, and the checks in the bole may collect enough moisture for local pockets of the fungi to develop (Hinds 1977*). In the Colorado study by Hinds et al. (1965), *Fomitopsis pinicola* (Swartz ex Fr.) Karst, extended upward for 10-15 feet (3-4.6 m). Furthermore, the basal section of the bole is frequently wetted by rain or snow, enabling basal decay fungi to readily develop. These fungi contribute to the weakening of the bole, decreasing resistance to windthrow.

Decay averaged about 1% per year; after 10 years, 11% of the volume was lost (Hawksworth and Hinds 1959). *Phellinus pini* (Thore ex Fr.) Pilat, a heart rot, was the most important fungus, accounting for 42% of all decay (Hawksworth and Hinds 1959). *P. nigrolimitatus* (Rom.) Bourd. et Galz caused 50% of the butt rot, while *F. pinicola* accounted for 66% of the sap rot (Hawksworth and Hinds 1959).

Later in the study, decay in standing trees averaged 12% of the volume within 20 years (Hinds et al. 1965). *P. pini* accounted for 3% of the total cubic foot volume and 24% of the total decay volume (Hinds et al. 1965). Also, *P. nigrolimitatus* had caused 6% of the total decay volume and 26% of the butt rot, while *F. pinicola* caused 9% of the total decay volume and 31% of the sap rot (Hinds et al. 1965). The differences in the rate of decay and the percent decay accounted for by each fungus in the two studies is related to the rate of development of the fungi and sampling procedures. Fungi develop rapidly after the trees die, and then their development levels off. As time passes, the trees with greater amounts of decay fall (fig. 11), while the sounder trees remain standing. These trees are thus removed from future sampling, so, later results tend to show lesser amounts of decay.



Figure 11.—Beetle-killed trees may stand for more than 25 years but eventually they fall, sometimes blocking trails or becoming a hazard for hikers.

Fallen trees in contact with the ground decay in 5 years (Schmid and Hinds 1974).

Checking commonly develops in beetle-killed spruce. Twenty-five years after infestation, 65% of the trees had one large season (deep) check and 15%-20% had two (Mielke 1950). Fifteen percent of the trees developed no large season checks but did have numerous small, shallow checks. Losses from the shallow checks are minimal since they can be slabbed off. Losses from the season checks were not high and may be compensated for by the reduced cost of logging (Mielke 1950). The season checks are a factor only when the trees are cut for lumber.

The development of checking varies among trees. Some begin checking before needle fall, i.e., 1-2 years (Mielke 1950). A tree infested in July and debarked by woodpeckers during the winter may be unmerchantable 1 year later (Hester 1960*). Nelson (1954) indicates that logging ceased about 3-5 years after the trees were infested, so apparently checking was complete in 5 years. Checking ceases after the wood dries. As noted by Hester (1960*), woodpecker activity may influence checking because the removal of the bark would accelerate the drying process. Perhaps those trees that incur heavy woodpecker feeding develop checks the first year while those without woodpeckering develop checks in 2 or 3 years.

Wood Products

Salvage of beetle-killed spruce can proceed for many years after the trees are killed depending on the product to be derived. Timber for sawlogs remained merchantable for about 5 years, then enough trees developed radial checking to make them unmerchantable for small sawn boards (Nelson 1954). Trees that have been dead for more than 5 years are currently being cut for use as house logs in log homes in southwestern Colorado. High quality particle board can be produced from beetle-killed Engelmann spruce even though it has been dead 10-12 years (Mueller 1959). Both the flakeboard and hammermilled type had strength properties competitive with particleboards from other species (Mueller 1959). The same timber may remain suitable for pulp for 20 or more years (Nelson 1954). Cubic foot volume per Engelmann spruce from the Routt National Forest, Colorado, ranged from 15 for a 10-inch (25 cm) tree to 196 for a 29-inch (74 cm) tree (Mogren 1958). The average cord consisted of 2.6 beetle-killed trees when such trees were utilized to a 5-inch (13 cm) top (Mogren 1958). Some 50 years after infestation, spruce were being cut for mine props (Schmid and Hinds 1974).

Each beetle-killed spruce deteriorates differently, so, merchantability of a stand is variable (see Deterioration). Enough trees may become unusable within a few years, causing the salvage cutting in the stand to become uneconomical. However, by designating a felling and skidding pattern like the herringbone design, as suggested by Schaeffer (1954), harvesting can proceed faster, more beetle-killed area can be covered, and harvesting losses in the residual stand can be reduced.

Detection and Evaluation

The forest manager needs to know if spruce beetles are present in his management area, their distribution, and the potential significance of the infestation. Translated into the terminology of the pest manager, these general questions mean detection and biological evaluations. Detection is the discovery of infestations in their earliest stage of buildup. A biological evaluation is an appraisal of the current and potential significance of the infestation.

Detection and evaluation of spruce beetle infestations are usually accomplished by surveys. The objectives of surveys are (1) to find incipient and outbreak type spruce beetle infestations, (2) to find areas of forest damage (blowdown, broken-off trees) that may contribute to an outbreak, (3) to measure beetle populations and their trend, (4) to estimate the number of infested trees within each infestation, and (5) to determine their concentration (Wilford 1965*).

In the past, the distinction between detection and evaluation has not always been clear because detection information was gathered during an evaluation survey, or because the two types of surveys were made together. This is not inherently bad, but it does create some confusion as to the allocation of costs and the type of information to be gathered on each type of survey. For this report, the discussion of detection (detection surveys) will be confined to the discovery or location of infestation. The gathering of all other information will be considered as part of the evaluation process.

Detection

Infestations are detected through a combination of ground and aerial observations. Detection on the ground can be accomplished by field surveillance, scouting, or a systematically designed survey. Field surveillance is the technique of being alert in the forest—constantly observing the trees for signs of an abnormal condition. Forest workers do this as part of their regular work. Scouting is also a means of detecting infested trees. Scouting follows a random course with no preset pattern and is the most feasible, relatively inexpensive method of detection (Wilford 1965*). Systematic ground surveys have also been used for detection although this type of survey has been used sparingly since the White River outbreak. They differ from scouting in that they follow predetermined cruise lines. Since definite routes are taken, the systematic design provides better knowledge of the distribution and location of the infested trees. Both scouting and the systematic plan record essentially the same information. The details of the survey, including equipment, organization of the survey party, classification of infested trees, etc., are thoroughly outlined by Wilford (1965*).

Aerial surveys are also used to detect spruce beetle infestations, especially in remote roadless areas. Such areas can be more rapidly surveyed from the air than from the ground (Wilford 1965*). Suspect areas are usually inspected from light planes flying parallel flight lines during the summer (fig. 12). Once a suspected area is located, a ground check is made. If an infestation is uncovered, then more intensive ground surveys are made.

Aerial surveys use both fixed-wing and rotating-wing aircraft. Fixed-wing aircraft can be used to detect large infestations in inaccessible areas, but are less adequate than helicopters for detecting small, incipient infestations (Landgraf 1960*). Helicopters also offer the following advantages over fixed-wing planes: (1) they can land and take off from parks or exposed



Figure 12.—W. F. Bailey sketch mapping spruce beetle infestations from a light plane. "Beetle" has surveyed Colorado's spruce-fir type for more than 20 years.

ridges which enables an observer to check a suspicious area that might be quite distant from the road; (2) they are more versatile aircraft and can operate at speeds as low as 20 miles per hour (30 km per hour) at tree-top level, in narrow drainages, although normal operating speeds are 40-50 miles per hour (64-80 km per hour), (3) they have superior forward and lateral visibility, and (4) they fly in more turbulent air conditions (Landgraf 1960*). Helicopters may also be more economical if ferry time is minimized and maintenance is performed in the field. However, on an hourly basis, helicopters are much more expensive.

The benefit-cost relationship of aerial detection surveys has always been questionable. Wilford (1965*) claimed that such surveys were too costly unless the aircraft was used concurrently for other insect surveys or forest functions. Since infested trees may have differential rates of fading, no fading for more than one year, or needle fall without a color change (Wear et al. 1966), detection can be difficult and the worthiness of the survey questionable.

Obviously, a favorable benefit-cost ratio depends on the successful detection of infested trees which is influenced by the status of the infestation. Low level infestations (not outbreaks) are most often detected from the ground (Wilford 1965*). Such infestations may be more conspicuous to aerial observers in winter when bark chipped off by woodpeckers builds up around the tree bases. Then, detection from a helicopter may be possible; less likely from a fixed-wing plane. However, even helicopter flights to discover such infestations are not usually feasible because the probabilities of missing infestations are too great (Wilford 1965*). Outbreaks are readily detected from the ground and more easily recognized from the air than low level infestations. Under outbreak conditions, detection becomes more certain and the benefits of the aerial survey more positive. The more favorable points under these conditions are counterbalanced by the idea that if the infestation reaches the outbreak level before it is located, our detection method isn't very satisfactory. Considering this evidence, current systematic aerial surveys of entire national forests may be unjustified even though they have been used more frequently in recent years than ground surveys.

In the future, scouting surveys around cutting areas, windthrow, road construction and other human activities may be the most frequently used detection technique. Lacking disturbed stands, surveys should be concentrated in high hazard stands. Aerial surveys with light planes will be used on a more limited basis because of the cost. Systematic ground surveys for detection alone will rarely be used because of their cost and because this type of survey gathers the type of information more common to the evaluation process. New areas of infestation may be located under a systematic evaluation survey, but this detection information will be incidental to the main purpose of the survey. These latter instances exemplify the overlap between detection and evaluations.

Evaluations

Spruce beetle evaluations are composed of three different aspects: (1) appraising the significance of the infestation (biological evaluation), (2) determining the cost-benefit relationship between values threatened and cost of suppression (benefit-cost evaluations), and (3) determining possible environmental impacts of the infestation and of suppression measures (environmental impact evaluations). This report is concerned mainly with the appraisal of the significance of an infestation and the techniques used therein.

Since biological evaluations seek to appraise the current and potential significance of an infestation, significant quantities of data must be gathered to make an appraisal meaningful. This is usually accomplished by (1) examining the brood in infested trees (fig. 13),



Figure 13.—Trends in beetle populations are based on examinations of brood in the bark. D. D. Lucht clearing branches prior to extraction of the bark sample.

and (2) surveying the infested stands. Frequently in the past, however, the evaluation consisted only of examining the spruce beetle brood and then using the numbers counted in a predictive sampling plan. Surveys to determine the size and intensity of an infestation were performed later, if additional stand information was desired or if the trend prediction indicated an increasing population.

A procedure for predicting trends in spruce beetle populations in standing trees is available, but none are available for populations in logging residuals and windthrow. Knight's sequential sampling plan permits populations in standing trees to be evaluated in June and in August-September (Knight 1960b). The June sampling can determine if control actions are needed immediately. Decreasing populations require no treatments; static and increasing populations are considered treatable. The August-September sampling determines whether the emerging beetles will kill the next year—(1) more trees than are presently infested (increasing), (2) about the same number (static), or (3) fewer trees (decreasing). The sequential plan is currently used in conjunction with a basic stand description to forecast population trends.

Predictive sampling plans are not available for logging residuals because of the high variability in brood. Brood counts vary between surfaces within cull logs, between logs, tops and stumps, and between transect lines (Schmid 1977). This complicates the development of a common denominator which would give a trend for all categories of logging residual (logs, stumps, tops) from the sampling of only one. Individual schemes could be developed for each category, but this may not be practical.

Predictive sampling plans are also not available for blowdown. A plan being developed should have a greater chance of being useful, since only one category of infested spruce is involved.

In addition to the trend in the beetle population, information on the size and intensity of the infestation, as well as the stand structure, is important. This information can be gathered from systematic ground surveys; the objectives of the survey dictate its sampling design.

Circular plots can be used to estimate the intensity of an infestation. One-tenth-acre (0.04-ha) plots established at 2-chain (40-m) intervals along parallel cruise lines generally give the most accurate results (Knight et al. 1956). The 1/20-acre (0.02-ha) plot is more advantageous when areas are heavily infested. Plots larger than 1/10-acre and strip methods are less accurate than the 1/10-acre plot (Knight et al. 1956). In recent years, the variable plot method has been used with a 20-basal-area factor prism on standard parallel cruise lines (Frye and Flake 1971, Acciavatti 1974). A combination strip and variable plot cruise may yield the most information for the money spent.

In the 1960's, aerial photos could not be recommended for surveys to determine Engelmann spruce mortality (Wear et al. 1966). Recently, large scale (1:2250) 70-mm infrared aerial photography has proven feasible for estimating the number of dead, formerly infested spruce (Lessard and Wilson 1977). Interpretation of such photography is most accurate when evaluated by experienced interpreters. However, the number of beetle-killed trees may be overestimated because snags (trees killed by unknown causes) are tallied as beetle-killed. Since the interpreters are counting trees bereft of foliage, this photography is good for assessing the extent and intensity of an outbreak but is not adequate for estimating the number of currently infested trees.

Moderate scale (1:8000) color aerial photography has also proven effective for estimating dead, formerly infested trees. (Rush et al. 1977). This scale of photography has the disadvantages inherent in the scale of photograpy of Lessard and Wilson (1977). Both types of photography also have the problem of underestimating dead trees when a stand is multistoried and the smaller dead trees are hidden below the dominants.

Suppression

Chemicals

Although much has been learned of chemicals and spruce beetles, the constantly changing legal status of chemicals prohibits definitive recommendations. What can be applied today may be prohibited tomorrow. Therefore, chemicals will be discussed regardless of whether they are currently registered or not. For current status, interested parties should contact their state or federal pest management office.

Dichlorobenzene.—The fumigant dichlorobenzene was toxic to the spruce beetle and was used with good effect on the control projects until it was replaced by ethylene dibromide (Nagel 1960*). Dichlorobenzene was obtained as a mixture of para and ortho isomers. For best results the ortho content had to be about 60% to hold the para in solution during the coldest treating weather (Nagel 1960*). Dichlorobenzene was replaced because its vapors were particularly disagreeable at high altitudes, and fuel oil was the dilutant (Nagel 1960*). Fuel oil added a six-fold volume to the

transportation burden, and, with water abundantly available in most of the spruce stands, this was not economical.

Eight or five pounds of orthodichlorobenzene in sufficient fuel oil to make 5 gallons (19 l) resulted in 99% beetle mortality when sprayed on logs with mature brood. The heavier dosage rate was also tested against hibernating adults in the bases of standing trees and resulted in about 100% mortality. Tests on a limited number of standing trees with 4 and 8 pounds (1.8 and 3.6 kg) of orthodichlorobenzene resulted in 92% and 94% mortality, respectively. From 1950-1952, it was used on the control projects in western Colorado (Massey and Wygant 1954).

Napthalene and Trichlorobenzene.—Chlorinated naphthalene and trichlorobenzene were not effective on beetles in logs at 1-4 pounds per 5 gallons (0.5-1.8 kg per 19 l) of carrier (Massey et al. 1953).

Ethylene Dibromide (EDB).—EDB was used extensively to fumigate spruce beetles during the White River outbreak when the development of an emulsion was completed in 1951 (Nagel 1960*). Addition of epichlorohydrin inhibited the erosion of storage containers and allowed EDB to be held in readiness for longer periods.

EDB applied in concentrations of 0.75 and 1.5 pounds per 5 gallons (0.3 and 0.7 kg per 19 l) of fuel oil to standing trees with all brood stages resulted in 98% and 100% mortality, respectively (Massey and Wygant 1954). Although mortality was 97% at 5 feet (1.5 m) above ground, it was considerably less than 50% at 15 feet (4.6 m) (Massey et al. 1953). The higher up the tree, the less effective EDB was, even with concentrations of 3 pounds per 5 gallons (1.4 kg per 19 l) of carrier. This suggests an application problem rather than a lack of effectiveness of the compound. Emulsions of EDB in water applied to logs and standing trees generally resulted in 95% or more mortality in test cases. The emulsion containing 3 pounds (1.4 kg) of EDB was used in the spruce beetle control project in Colorado. One pound of EDB per 5 gallons (19 l) of fuel oil is considered effective in British Columbia (Grant and Cottrell 1968).

More recently, concentrations of 0.25, 0.75, and 1.25 pounds of EDB per 5 gallons (0.1, 0.3 and 0.6 kg per 19 l) of fuel oil caused 100% mortality in limited numbers of cull logs when applied to the point of runoff (Schmid 1972).

Dichloroethyl Ether.—Dichloroethyl ether in oil solutions were just as effective as EDB against all stages of the beetle (Nagel 1960*). Four pounds (1.8 kg) of the compound per 5 gallons (19 l) of fuel oil caused 100% mortality in standing trees when applied in late September (Massey et al. 1953). Dichloroethyl ether did not corrode iron or solidify until about -55° F (-48° C) and was quoted at half the price of EDB in 1955 (Nagel 1960*). Its disadvantages—flash point of 131° F (55° C), more dichloroethyl ether needed than EDB per 5 gallons, and disagreeable odor—may have eliminated its use.

Fuel Oil.—Fuel oil by itself caused mortality against broods in cull logs (Schmid 1972). In later testing, mortalities ranged from 76% to 100%. The fuel oil was more effective when the brood was mostly larvae rather than callow adults.

DDT.—A 4% solution of DDT in fuel oil applied to infested logs and standing trees resulted in 100% mortality in the adult stage but 97% and 76% mortality in the larval stage in both types of host material respectively (Massey and Wygant 1954). Tests on host material predominantly infested with larvae and pupae generally resulted in less than 50% mortality. DDT did not act as a fumigant, so, it was rather ineffective on the larvae within the phloem. Adults received a lethal dose as they emerged from the bark. Mortality was not accurately determined because the adults were still capable of departing from the log even though they died later.

Benzene Hexachloride (BHC).—An emulsion of BHC (enough BHC in the oil to give 0.46% of the gamma isomer) resulted in 92% and 90% mortality of the adult and 97% and 92% mortality of the larval stages in logs and standing trees respectively (Massey and Wygant 1954). However, BHC in oil alone resulted in less than 50% mortality.

Silvisar 510.—Silvisar 510 (S 510) was developed as a herbicide for thinning stands of conifers and hardwoods. The lethal component in S 510 is cacodylic acid, a highly water-soluble pentavalent arsenic compound. Cacodylic acid kills the crowns of trees mainly by desiccating the meristematic tissues of buds and new twigs (Smith 1966). It also affects the abscission layer of the leaf. S 510 has a low order of mammalian toxicity and is relatively nonirritating to skin and eyes (Chansler and Pierce 1966).

S 510 has come to be commonly called cacodylic acid because its lethal ingredient is the acid. This has led to some ambiguity because other trade name chemicals (Ansar 160, Silvisar 550) contain cacodylic acid but have different concentration of cacodylic acid as well as different formulations per unit of solution. Even with S 510, the concentration of cacodylic acid has varied (see footnotes of Buffam and Yasinski 1971, Buffam 1971). Since different formulations may produce significantly different effects, it is important to specify which cacodylic acid containing solution is

being discussed and erroneous to call any such solution just "cacodylic acid."

S 510 has been used against the spruce beetle in two ways—post-attack injections and lethal trap trees (see Trap Trees section). In both methods S 510 is injected into the tree through frills in the bark in the same manner (fig. 14) but the former method receives the injection after the beetles have attacked standing trees while the lethal trap trees are injected and felled well before beetle attack. In both instances, the silvicide causes short "U", "S", or "Y" shaped galleries which are void of packed frass (Frye and Wygant 1971).



Figure 14.—C. K. Lister frilling a tree prior to injection of Silvisar 510.

Chansler and Pierce (1966) initiated the first testing of S 510 against spruce beetles with a post-attack injection of S 510 and Ansar 160. They obtained an 87% reduction in the brood. Egg hatch was less and the first instar suffered the greatest mortality (Chansler and Pierce 1966). Subsequent testing yielded 94% and 100% mortality for half- and full-strength S 510 treatments respectively (Frye et al. 1977). When injected at 3 feet (.9 m) above ground in mid-July, these strengths gave satisfactory control of beetles attacking the first week of July.

The lethal trap method has progressed from a single injection of one dosage rate, to various injection times, dosages, and felling times. Initial tests yielded satisfactory mortality with full-strength treatments (Buffam and Yasinski 1971, Frye and Wygant 1971). Later tests indicated half-strength treatments are just as lethal as full-strength treatments (Buffam 1971, Buffam et al. 1973, Minnemeyer 1975, Lister et al. 1976). Injections in late September or October may be ineffective if the dosage is injected after the translocation process of the spruce has dropped sharply (Buffam et al. 1973). Quarter- and tenth-strength treatments give unsatisfactory mortality (Lister et al. 1976).

Arsenic concentrations have been determined for the phloem, needles, cones, and soil. Concentrations in the phloem are highest near the frill and relatively constant above 15 feet (4.6 m). In lesser strength treatments, mortality is unsatisfactory in the upper sections of the tree because insufficient material is translocated. Arsenic concentration in the needles is higher than in the cones while the concentration in the phloem and cones is comparable (Lister et al. 1976). Concentrations in the soil were not significantly different between pre- and postinjection samples (Lister et al. 1976). The first few inches of soil have a natural level of arsenic. There is no appreciable leaching or passage from the roots into this soil within the first year after injection. In laboratory cultures, cacodylic acid did not seriously affect forest soil microbial populations or their decomposition of organic matter (Bollen et al. 1974).

Protective Sprays

Protective sprays such as lindane, Sevimol, etc., have not been intensively studied as with other *Dendroctonus* beetles. DDT was tested in the 1940's but produced erratic results on standing trees and logs (Nagel 1960*). Preflight application of 0.5% lindane on frontalin-baited trees killed most of the attacking adults and prevented tree mortality (Dyer 1973). A later test with frontalin and 0.5% lindane resulted in 5% tree mortality but killed 44,000 attacking beetles (Dyer 1975). In both of Dyer's tests, trees were only sprayed on the lower 10 feet (3 m), so, spraying to a higher level may provide better protection.

Although protective sprays have not been as thoroughly studied against the spruce beetle, there is no reason to believe they would not be as effective against it as they are with other *Dendroctonus* species. As with other *Dendroctonus* species, their use may be restricted to the protection of high value trees.

MCH, the natural antiaggregative pheromone of the spruce beetle, prevents attacks on normally attractive host material (Rudinsky et al. 1974, Furniss et al. 1976). This compound probably reduces attractiveness rather than repels the beetles.

Pheromones

Frontalin, the principal pheromone of the southern pine beetle (*D. frontalis* Zimmerman) is a compound

of spruce beetle secondary attraction (Dyer and Chapman 1971). In Canada, it, plus alpha-pinene, beta-pinene, or 3 carene, attracts beetles better than uninfested billets (Dyer and Chapman 1971). More recently, seudenol and alpha-pinene attracted more beetles than frontalin and alpha-pinene (Furniss et al. 1976) although seudenol attracts predominantly males, while frontalin attracts 60%-70% females. However, female infested billets are more attractive than any of the frontalin-terpene combinations (Dyer and Chapman 1971). Logs with one unmated female attract more beetles than unifested logs or logs with pairs of beetles (Dyer and Taylor 1968). Frontalin on spruce trees induces attacks, and natural secondary attraction develops even though the beetles can not overcome the tree resistance (pitch) (Dyer 1975).

The spruce beetle also responds to the secondary attraction of the Douglas-fir beetle (*D. pseudotsugae* Hopkins) in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) as well as in white spruce logs (Chapman and Dyer 1969). Adults will land on the Douglas-fir logs but will not create galleries in them.

MCH (3-methyl - 2-cyclohexen - 1-one), the natural antiaggregative pheromone of the Douglas-fir beetle, represses spruce beetle attacks; reducing the attraction of spruce beetles on beetle-infested logs by 99% (Kline et al. 1974) and the number of attacks on spruce bolts (Furniss et al. 1976). MCH is released when a male enters the recently created female gallery but which sex produces the compound is unknown (Rudinsky et al. 1974). Liquid MCH deployed in glass vials along the tree trunk reduced attack densities to 0.01 per square foot (929 cm^2) (Rudinsky et al. 1974). Granular MCH completely protected logs during the first two flight periods but decreased in effectiveness over time. At the end of eight weeks attacks were one-fourth as numerous as on the control trees (Rudinsky et al. 1974).

Pheromone baited standing trees for control purposes are seriously hampered by windfall (Dyer and Safranyik 1977). Windfall may so reduce the efficiency of the baited trees that 34 trees must be baited for each windfall to trap 90% of the population (Dyer and Safranyik 1977). Unless more efficient pheromones or pheromone dissemination methods are found, the effectiveness of pheromone baiting to manage spruce beetle populations over large areas is limited.

Trap trees

Trap trees are living, merchantable-sized spruce which are felled to attract infestations of the spruce beetle (Nagel et al. 1957). The main objective of the trap tree is to decoy the beetles away from living, standing trees. Once the trap tree is infested, it can be milled, burned, solarly heated, or treated chemically. Trap trees effectively attract beetles up to one-quarter mile (0.4 km); less effectively up to one-half mile (0.8 km) (Nagel et al. 1957).

In Colorado, trees felled in the fall were more attractive to the beetles than trees felled in the spring (McComb 1953), although the spring-felled trees were cut after beetle flight began. In the northern Rocky Mountains, trap trees felled in May or June prior to beetle flight were preferred over trees felled the previous September (McComb 1955). The spruce forest in Colorado commonly has considerable depths of snow in May which often precludes the felling of trap trees before beetle flight.

Trees felled in the shade sustained more attacks than those felled in the sun (Nagel et al. 1957). Unbucked trees may make better traps than bucked trees because the branches may shade the bole and also hold it above the ground to lessen the development of fungi (Wygant 1960*). Bucked trap trees, while easier to handle at a later date, have a greater chance of settling in the duff and thus precluding attacks along the bottom surface.

The trap tree method has been modified in the last few years (see Section on S 510, Frye and Wygant 1971, Buffam 1971, Buffam et al. 1973, Lister et al. 1976). Prior to felling, the trees are injected with silvicides. These arsenical compounds are translocated throughout the bole. When the tree is attacked after felling, they cause mortality to the brood. The lethal trap tree has two advantages over the traditional trap tree; the brood is killed in the tree so that further treatment is not required, and the negated postattack treatment means that trap trees can be created quite distant from a road system.

The lethal trap tree method has also been further modified in that the injected trees were not felled. These have not been as effective as the traditional traps since beetles prefer the downed material.

Resistant trees baited with frontalin are also potential traps in which reproduction is prevented and many parent adults die (Dyer and Safranyik 1977). Attacks in standing trees are induced by the frontalin, but the tree resistance (pitch) can not be overcome.

Traditional trap trees have three advantages over standing trees for absorbing beetles: beetles prefer downed material; beetles infest a greater proportion of the bole; and mean attack density is greater. The combined effect of these factors means a larger number of beetles are absorbed in the traditional trap tree.

Comparing attack densities from different studies, an 18-inch (46-cm) shaded trap may absorb 8 to 14 times as many beetles as an 18-inch (46-cm) standing tree (tables 2 and 6). In one field test, a windfall absorbed about four times the number of attacks as a baited standing tree (Dyer and Safranyik 1977).

The number of trap trees to be felled depends on the attacking beetle population and the size of the traps. Since the trap tree may absorb 10 times the number of beetles a standing tree will absorb (Wygant 1960*), the number of traps will be less than the number of infested standing trees. Nagel et al. (1957) recommended one trap for every four to five infested standing trees, while Wygant (1960*) recommended the following ratios: 1:10 for static infestations and 1:2 for increasing infestations. A more precise number to be felled may be calculated using table 6 if an estimate of the beetle population and size of the prospective traps are known.

Where the trap trees are to be felled by a logging contractor, Hester (1960*) advises the trap trees be high quality trees, located in accessible places and in groups of 50 to 100. This encourages the operator to remove the material at the proper time. When only four or five trees are felled away from haul roads, operators resist returning for them, or they may be forgotten because of their small number (Hester 1960*).

Table 6.—Number of beetles absorbed by a trap tree of specific diameter based on attack densities from McComb 1953 and Lister et al. 1976. Densities for the top and lateral sides not available in Lister et al., so they were derived from McComb's data in the same proportion as the bottom samples.

DBH	McComb 1953		Lister et al. 1976
	Sunlight	Shade	Partial Shade
6	238	586	114
7	584	1,386	268
8	720	1,770	344
9	976	2,398	464
10	1,220	2,996	580
11	1,502	3,690	714
12	1,800	4,422	856
13	2,412	5,926	1,148
14	2,678	6,580	1,274
15	3,078	7,566	1,466
16	3,474	8,538	1,654
17	3,886	9,550	1,850
18	4,326	10,630	2,058
19	4,786	11,762	2,278
20	5,312	13,054	2,528
21	5,822	14,306	2,770
22	6,352	15,610	3,024
23	6,906	16,970	3,286
24	7,480	18,382	3,560
25	8,082	19,860	3,846

Provision for trap trees and their subsequent removal may be a stipulated requirement in the timber sale agreement, since trap trees left unattended in the forest may contribute to the buildup of beetle populations. Hester (1960*) lists the following clause as one possible addition to a logging contract for spruce:

> "The purchaser will be required to fell a number of green trap trees as designated by the Forest Service. These trees will be felled after September 1 and will be left unlimbed and unbucked until the spruce beetle flight has taken place the following summer. This material will be removed by logging after August 1 the year following cutting, provided that the maximum number of trap trees required during the period of this contract shall not exceed 10% of the volume of the sale."

Frontalin baited trap trees also attract clerid beetles (Dyer 1973). This is advantageous in a suppression program because the clerids arrive before the spruce beetle and then may consume the maximum number of spruce beetles. It is a disadvantage, however, if the baited trees are treated with an insecticide because the clerids are killed along with the beetle.

Silvicultural Treatments

Alexander (1973) suggests several modifications in cutting treatments if spruce beetles are a threat. When spruce beetles are present in the stand to be cut or in adjacent stands in sufficient numbers to pose a threat, and less than the recommended percentage of basal area to be removed is in susceptible trees, Alexander suggests any attacked and all susceptible trees should be removed in the first cut. This will remove most of the larger spruce and is, therefore, a calculated gamble in above average wind risk situations. Subsequently attacked trees should be salvaged. If more than the recommended percentage of basal area to be removed is in susceptible trees, three options are available: (1) remove all the susceptible trees, (2) remove the recommended basal area in attacked and susceptible trees and accept the risk of future losses, or (3) leave the stand uncut. If the stand is left uncut, probably less than half of the residual basal area would be lost, but most of the surviving merchantable spruce would be of small diameter.

There are no precise guidelines for cutting old growth spruce and maintaining low beetle populations. Some guidelines are indirectly available from the stand rating system of Schmid and Frye

(1976). High risk stands are located on well-drained sites in creek bottoms, have an average diameter of live spruce more than 16 inches d.b.h., have a basal area of over 150 square feet per acre (14 m^2 per 0.4 ha), and a proportion of more than 65% spruce in the canopy. Since the beetle prefers older, larger diameter trees, they should be removed first while trying to lower the basal area, average diameter or percent composition of the stand. Generally maintaining these stand characteristics below the high risk level may be effective guidelines.

Guidelines for handling logging residuals are available (Schmid 1977). Trees should be cut as low to the ground as possible to reduce stump height, preferably less than 1.5 feet (0.5 m). Cull logs and tops should be limbed and the branches kept away from the bark surface of the bole. After limbing, the cull logs and tops should be positioned away from any shade and left unpiled unless they are to be burned. Their directional orientation is not important. Logs and tops should be cut into short lengths, the shorter the better. While full length logging removes the merchantable host material (Beckwith et al. 1977), complete removal or destruction of all cull logs and tops would eliminate the most significant host material left in the woods. If trees are logged full length, then the diameter of the small end should be 3 to 4 inches (7.6-10.2 cm).

Except for complete elimination of host material, even the previous recommendations will not keep beetles from inhabiting the bottom surfaces of logs and tops. If high beetle populations are subsequently found in these surfaces, they should then be treated by solar heat, with chemicals, or burned.

Where a substantial spruce beetle population exists in the adjacent forest, it may be wiser to leave the logging residuals rather than remove or destroy them immediately after cutting. Since the beetles will seek host material as they emerge, suitable residuals will attract beetles and reduce mortality of standing trees. After infestation, the residuals must be removed or treated.

These logging residual guidelines are applicable under selective, shelterwood, or clearcut silvicultural systems. The selective system offers more shade for the residuals than does a clear cut. Under a selective system, prompt removal may be the best guideline.

The guideline for windthrown trees—salvage as soon as possible, or desirable. The lone exception is the situation where removal encourages further uprooting of the edge of the stand. In some clearcut areas, trees have been windthrown along the edge. Within 1-2 years they have been removed because of the potential beetle threat, but then further windthrow occurred. Rapid removal prevented the edge trees from developing wind firmness (Alexander 1976*). In this situation, it may be better to leave the windthrown trees to the beetles even if a few adjacent standing trees are sacrificed. An intensive evaluation of the adjacent stand and the beetle population using the risk rating system of Schmid and Frye (1976) and the blowdown prediction system of Schmid (1978*) would determine whether to salvage or leave the windthrown trees.

Beetle Management Policy

Historically, control efforts usually began after an infestation had caused substantial tree mortality (hundreds of trees). Efforts emphasized sanitation cutting and chemical spraying. Few stands received preoutbreak actions designed to reduce or eliminate tree mortality (Schmid and Frye 1976). This is a questionable approach. In an economic analysis of the White River outbreak, Vaux (1954) notes that the total value of the protected spruce resource was about equal to the cost of the program. Net benefits were confined to the saved recreational values; other considerations (i.e., watershed protection, fire hazards and wildlife population changes) could not be assigned economic values. Vaux further notes that, unless the competitive disadvantage of the spruce resource changes, the value of the timber and hence the benefit-cost ratio would not change.

If forest managers are to move away from this post mortem approach — always waiting until the infestation kills hundreds of trees before initiating action — and begin to manage beetle populations, then effort must be made to reduce the potential for a beetle outbreak. Vaux suggested such a change in 1954, stating "the job of forest insect . . . control can not be appraised on a merely technical level. It must be considered as an integral part of the whole program of forest development and management." We suggest a first step in this direction would be to determine the management objectives for each spruce-fir stand, and in accord with these objectives, designate each stand as a beetle management or no management area.

Areas designated as beetle management areas could receive either silvicultural or suppressive action. The particular action prescribed for each stand would vary. Some stands might receive light thinning or harvest cuts, while other areas might receive direct and intensive suppressive actions. Areas with endemic infestations may only be surveyed periodically until the infestation warranted remedial action. The main characteristic of each stand with a beetle management classification is that the stand could, if necessary, receive either direct or indirect suppressive action.

The primary management objective in the beetle management stands may be timber production, but even good timber producing stands may have another objective with higher priority. In fact, those stands with timber production as the primary objective may be in the minority. Vaux (1954) notes that 70% of the forest land in Colorado is in public ownership. As such, it is subject to multiple use considerations, and timber production must, therefore, compete with other uses — recreation being currently a much more potentially dominant future use.

In contrast, nonmanagement stands would not receive silvicultural or suppressive actions. Beetle populations would be allowed to increase and subside at their natural rate. They may decimate the spruce in a particular stand(s) but this does not mean the area or the beetles would be totally ignored. On the contrary, the population might be periodically evaluated since it could always disperse into an adjacent and possibly beetle management area and cause undesirable tree mortality. The most obvious example of nonmanagement areas is wilderness, although natural areas, National Parks, experimental forests and private land may also be included.

A further and simultaneous step in the spruce beetle management area would be to rate each stand into a potential outbreak category using the system of Schmid and Frye (1976). This would benefit the forest manager by: (1) identifying the stands most likely to have outbreaks, and (2) providing the impetus for active involvement in a neglected aspect of beetle management: modifying stand conditions. The manager could direct his silvicultural activities into stands with the highest outbreak potential.

The promotion of preoutbreak silvicultural practices and stand ratings does not mean that suppressive activities should be abandoned. Some areas may need suppression programs because: (1) silvicultural activities can only proceed at a certain rate, so that years will pass before all of the beetle management stands receiving silvicultural treatment will be in a low potential outbreak status, and (2) suppressive action may be the best short-term measure. The State of Colorado has about 3.4 million acres (1.4 million ha) of spruce-fir sawtimber on commercial forests (Alexander 1974), most of which is old-growth and 75% of which is in either roadless or reserved categories (Cahill 1976*). Although large areas of old-growth forests are being converted to timber producing stands that must be managed (Alexander et al. 1975), the rate of conversion is less than 0.5% per year. At this rate, it will take more than 100 years to convert the old-growth, and thus, substantial acreages of old-growth will continue to exist for at least 50 years.

Suppression measures will be needed for the short-term because silvicultural activities will not proceed fast enough. They will also be needed for the long-term because (1) some stands, even though designated as beetle management areas, will not receive silvicultural treatment because their primary management objective will be something other than timber production, and (2) measures must be available to handle instances when beetles in nonmanagement areas are a threat to a managed area. Whenever possible, suppression measures should be linked to a silvicultual treatment so that the stand conditions contributing to the infestation are modified and the inevitable is not just temporarily postponed.

Some will question the effectiveness of suppression programs as well as these proposed approaches to beetle management. Suppression methods can always stand improvement, but ineffectiveness is generally the result of an incomplete job. Chemicals, for example, will satisfactorily suppress populations in cull logs, but only if the logs are sprayed completely. If not enough trap trees are felled to absorb the emerging beetles, standing trees will be infested. Or an outbreak may become so large that the suppression program is inadequate. The program manager may then treat the most accessible or least costly trees in order to maintain the lowest possible treatment cost per tree. This action frequently expands the treatment program to a large area rather than confining it to a particular drainage. As a result, the percentage of untreated trees in a specific drainage may be high so the outbreak continues. Actually, suppression in the properly treated trees was satisfactory, but since so many trees remained untreated, the treatment appears ineffective. Obviously these situations must be eliminated and the undesirable side effects of such programs minimized. Otherwise, the public, through law or departmental edict, will restrict our options which may seriously handicap suppression efforts.

In summary, we have enough knowledge of the beetle and suppression techniques to prevent large infestations if we desire. Basic to the development of a control strategy is a need to know the objectives for the particular stand(s). If the objectives are known, then we can begin to integrate beetle management into forest management.

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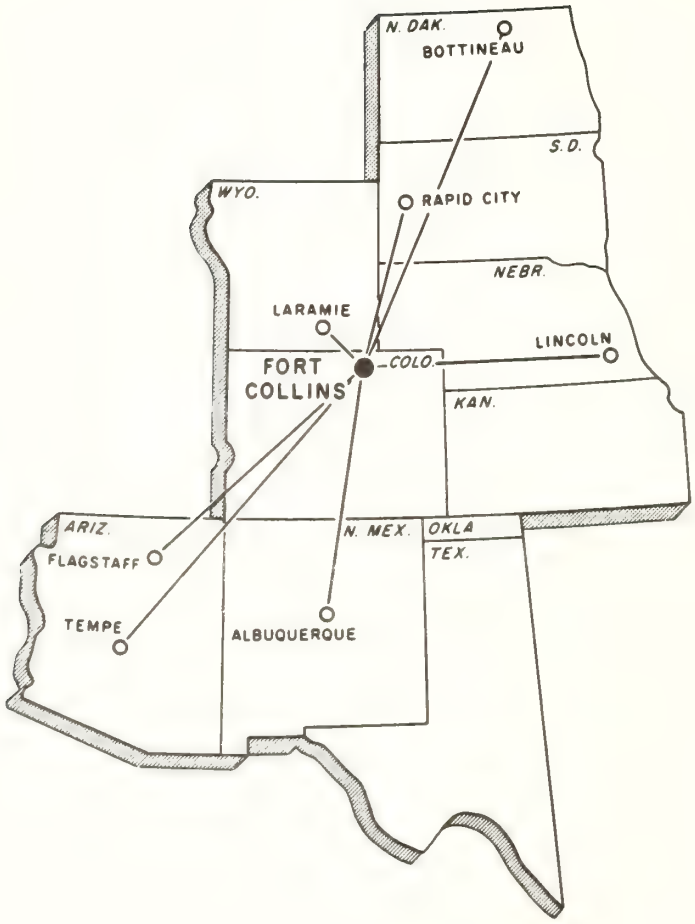
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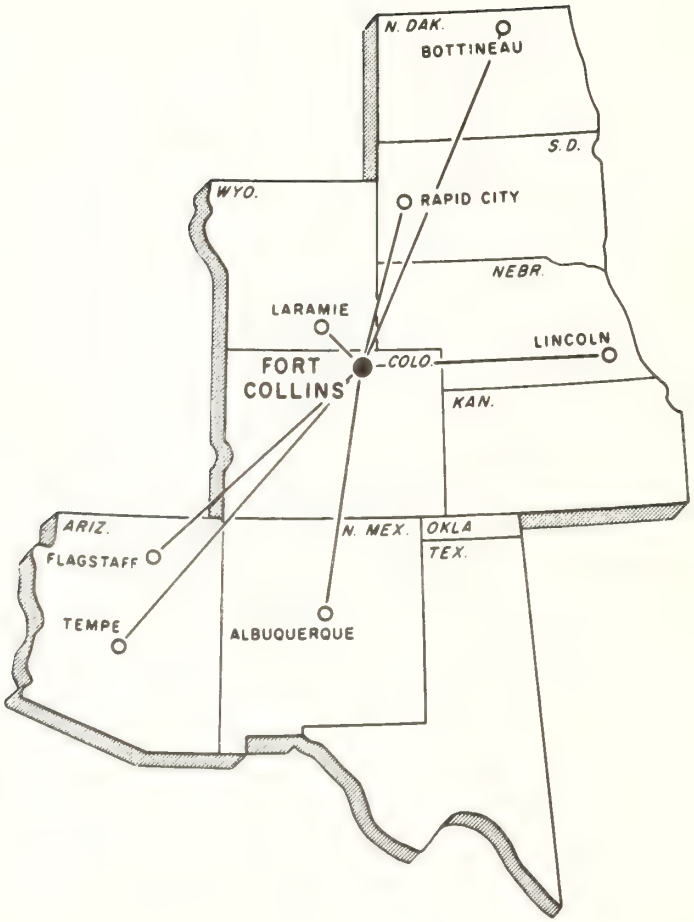
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Forecasting Seed Crops and Determining Cone Ripeness in Southwestern Ponderosa Pine

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General Technical Report RM-50
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U. S. Department of Agriculture

Forecasting Seed Crops and Determining Cone Ripeness in Southwestern Ponderosa Pine

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Abstract

Cone crop forecasting is important for planning regeneration cuttings and seed collections. Knowledge of time and rate of flower and cone development is essential. An early July flower and conelet inspection serves two purposes: (1) a flower count detects 15 months in advance the possibility of a cone crop the following year; (2) a conelet count checks progress of the current year's cone crop. Flower and conelet observations and cone collections should be made on dominant trees larger than 12 inches d.b.h. A population mean cone specific gravity of 0.88 coincides with the time 80% of the seeds are mature. When 13 or more of 25 cones in a sample float in SAE 10W or 20-20W motor oil, it is safe to begin collections in the area sampled.

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Forecasting Seed Crops and Determining Cone Ripeness in Southwestern Ponderosa Pine

W. J. Rietveld

Management Implications

Both natural and artificial regeneration depend upon seed supply, which varies from year to year. If the relative number of ponderosa pine flowers could be used to estimate potential yield of cones 15 months in advance, and were verified 3 months before seedfall, it would help planning in several operational phases of forestry. Seedbed preparation and timber harvesting could be timed with seed crops to ensure adequate natural regeneration. Because heavier seed crops contain the best quality seed (Fowells and Schubert 1956, Larson and Schubert 1970) and can be collected at lower cost, plans can be made to collect ample seed for artificial regeneration during favorable seed years (fig. 1). Good pine seed can be stored without serious loss of viability for at least 2-5 years (Fowells and Schubert 1956).



Figure 1.—A heavy ponderosa pine cone crop shedding seed in mid-October. Medium to heavy cone crops are relatively easy to forecast, and should be favored for seed collection.

Phenology of Flowering and Cone Development

Understanding the time and rate of development of flowers and cones, and recognizing certain stages of development at certain times, we can estimate the size of a cone crop up to 15 months in advance and monitor its progress. Phenology involves timing of plant growth, and development with seasonal changes in climate. Timing of the flowering and fruiting process in ponderosa pine is very closely tied with climatic changes during the year.

The general sequence and phenology of flowering and conelet development in southwestern ponderosa pine is outlined in table 1.[2] Portions of three years are required in development of a future cone crop: (1) initiation of floral primordia in the first year, (2) development of flowers and conelets the second year, and (3) fertilization and maturation of cones in the third year.

[2] *More detailed descriptions of flowering and conelet development in* Pinus *can be found in Gifford and Mirow (1960), Kozlowski (1971), and USDA (1974).*

Table 1.—Sequence and timing of events of flowering and conelet development of southwestern ponderosa pine.[1]

Event	Month of occurrence or duration	Elapsed time *(months)*	
		From primordia	From flowers
Flower primordia are differentiated in buds	August	0	
Male and female flowers first become visible on elongating shoots (fig. 2)	June	10	0
Pollination and pollen tube development	Mid-June—early July	10.5	0.5
Resting period (fig. 3)	July—May	21	11
Fertilization	June	22	12
Post-fertilization cone enlargement	June—mid-Sept	24.5	14.5
Cone and seed maturation	Late Sept—Oct	25.5	15.5
Cone opening	Mid-Oct—Nov	26	16

[1] *Data assembled from Pearson (1931), personal communication with Dr. John A. Pitcher (Regional Geneticist, USDA For. Serv. R-3), and personal observations.*

Both male and female flowers occur separately on the same tree. Male and female flower primordia—microscopic stages of the flowers—are formed in the winter buds at the end of the growing season. Flowers first become visible to the eye the following spring when they emerge from expanding buds. Male flowers (fig. 2a) usually appear one to two weeks before the females. They form at the base of the current year's growth, mostly on older lateral branches in the lower crown. Female flowers (fig. 2b) appear at the tips of the current year's branch growth, usually in the upper crown at the ends of the main branches.

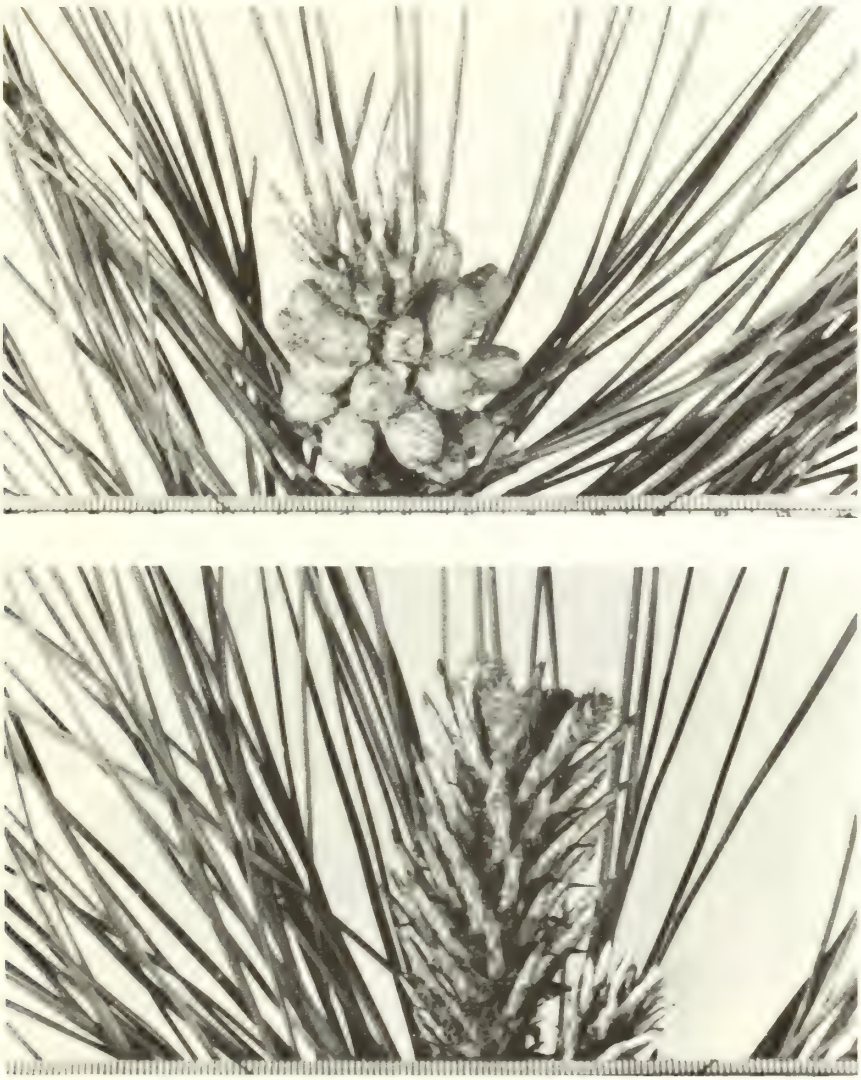


Figure 2.—(a) Male flowers of southwestern ponderosa pine nearly ready to release pollen, and(b) female flowers nearing receptivity in mid-June. The male flowers appear first; note their location at the base of the new shoot. The female flowers appear in groups of one to five near the tip of the new shoot.

Male flowers occur in clusters of a few to 30 (fig. 2a). Before ripening they are usually green, but somethimes have a reddish tinge. They are yellow to light brown at the time pollen is shed, and then turn brown. Female flowers are usually green (fig. 2b), but sometimes they are red to purple. At the time of pollination, female flowers are about one-half inch long. The flowering period lasts about three weeks. Male flowers fall soon after pollen is shed, while the pollinated female flowers develop slowly and eventually become the mature cones.

It is important to note that floral initiation varies as much as 2-3 weeks and varies in different parts of the forest and the region, depending on weather and site conditions.

Pollen tubes initially develop rapidly, then rest for several months. By fall, conelets are still quite small—only about one-tenth the size of mature cones (fig. 3). Pollen tube development is completed, and fertilization takes place in early summer the following year.

Conelets enlarge rapidly following fertilization and become full-size cones by mid-September. Growth of the new shoot places the developing cones in a lateral position. As cones mature, they gradually change from green to brown.



Figure 3.—Conelets in mid-October are very small and difficult to see from the ground. They are dormant in winter. Pollen tube development will be completed early the following spring, fertilization will occur, and the ovulate (fertilized) conelets will enlarge rapidly during the summer and mature in the fall.

It is uncertain how much the time of seed maturity varies with elevation, but the time of cone opening depends on the drying conditions at different locales. Both seed maturity and cone opening vary considerably with different seed crops. The elapsed time for initiation of floral primordia to cone maturity is approximately 26 to 27 months, and from flower initiation to cone maturity it is 15 to 16 months.

Forecasting and Rating Methods

Timely observations of female flowers and developing ovulate conelets are the basis for forecasting probability of a good seed crop. The key factors are: (1) when and how the trees are observed, (2) what is looked for, and (3) how what is seen is translated into a cone crop prediction. These factors are the basis for a cone crop forecasting and rating system. Since, the third factor already has been dealt with (Schubert and Pitcher 1973), the first two will be emphasized.

With practice, it is not difficult to spot and count (using binoculars) the female flowers on the elongating shoots of trees up to 50 feet tall. The main interest is in the female flowers before they become cones. It is best to observe the trees in early July because any female flowers have appeared by that time and are not yet obscured by needles (fig. 2b). After late July, the elongating needle fascicles on the new shoots hide the conelets. Also, in early July the fertilized, enlarging ovulate conelets below the base of the current year's growth can be counted. These will be slightly larger than those pictured in figure 3, and will be the current year's cone crop.

The early July inspection serves two purposes: (1) to estimate the potential cone crop for the following year (15 months in advance), and (2) to monitor the progress of the current year's cone crop (3 months in advance). It is recommended that the forester responsible for regeneration on each District go into the field in early July of each year (with binoculars and data sheet) to make the observations needed for cone crop forecasts. Additional observations are desirable when a good cone crop is in progress, and the rapidly enlarging cones become easier to count.

The next considerations are: (1) which trees to observe, (2) how the cone crop rating system works, and (3) what size a worthwhile cone crop is. Dominant trees over 12 inches in diameter with full, vigorous crowns are considered to be good seed trees (Schubert and Pitcher 1973). Dominant trees over 19.5 inches d.b.h. are the best seed producers (Fowells and Schubert 1956), but are difficult to observe and collect from unless a timber sale can be scheduled at the time cones are ripe (about a 3- to 4-week period).

The 10-unit cone crop rating system (table 2) recommended by Schubert and Pitcher (1973) has been used successfully in California since 1955. It is based on a spring or early summer conelet inventory of dominant trees over 12 inches in diameter, which is a 3- to 5-month forecast of the size of the current cone crop. At least 10 trees should be inventoried in a proposed

Table 2.—The 10-unit classification for rating cone crops on conifers in Arizona and New Mexico (from Schubert and Pitcher 1973).

Classification	Description[1]
1 None	No cones on any seed tree.
2 Very light	Few cones on less than one-fourth of the seed trees.
3 Very light to light	Few cones on one-fourth to one-half of the seed trees.
4 Light	Few cones on more than one-half of the seed trees.
5 Light to medium	Few cones on more than one-half and many cones on less than one-fourth of the seed trees.
6 Medium	Many cones on one-fourth to one-half of the seed trees.
7 Medium to heavy	Many cones on more than one-half of the seed trees.
8 Heavy	Many cones on more than one-half of the seed trees, with less than one-fourth to one-half of them loaded with cones.
9 Heavy to very heavy	Many cones on more than one-half of the seed trees, with one-fourth to one-half of them loaded with cones.
10 Very heavy	Many cones on more than one-half of the seed trees, with more than half of them loaded with cones.

[1] *Cones per tree: few = 1 to 20; many = 21 to 160; loaded = 161 or more.*

collection area to give an accuate estimate of the crop. Both female flowers and ovulate conelets should be inventoried in early July, and both current cone crop and next year's cone crop should be rated according to the system in table 2. For a single cone crop, this approach gives both an advance indication (15 months) and current forecast (3 months) of cone crops to provide maximum time for planning. It is further recommended that flower and conelet observations and cone crop forecasts be made for the individual tree seed-zones proposed by Schubert and Pitcher (1973). Forecasts may not be necessary for all seed-zones, only for those where seed or seeding is needed.

Although female flowers are more difficult to see and count than developing cones, the forester should persevere and make the best flower counts he can. The flower count is very important since it detects the beginning of a cone crop well in advance and gives an estimate of its possible size. This allows adequate time to watch the cone crop and plan cultural treatments and collections as it materializes.

When few or no female flowers are observed in early July, it can be concluded that there will be no local cone crop the following year. When a significant number of flowers per tree are counted, it must be remembered that the conelet count almost always will be lower than the flower count because of such factors as flower and conelet abortion, insects, and severe late freezes. Severe freezes during the flowering/pollination period are

uncommon, but may inflict severe losses when they occur. Abert squirrels may destroy 25% or more of the conelets or cones (Larson and Schubert 1970). Cone insects and squirrels are usually more of a problem to light to moderate cone crops. The point to remember is that moderate attrition of flowers, conelets, and cones is to be expected, and total crop failures are not unusual.

Only medium to heavy cone crops should be considered for seed collections. Smaller cone crops might be utilized for regeneration cuttings, but the risk of failure is greater. The best seed, in terms of soundness and viability, is produced in heavier seed crops (Fowells and Schubert 1956, Larson and Schubert 1970). During heavy seed crops, cone losses to squirrels and insects, and seed consumption on the ground by rodents and squirrels are less serious, leaving a greater proportion of the seed crop for collection or natural regeneration. Collection costs are lower during heavy seed years. Enough seed can be collected and stored from heavier seed crops to supply the needs during the years of poor seed crops.

Additional information on cone production and seed characteristics in southwestern ponderosa pine may be found in Larson and Schubert (1970), Schubert and Pitcher (1973), and Schubert (1974). Larson and Schubert (1970) developed a method to predict cone crop size based on counting conelets on twigs clipped by squirrels. This method is useful to detect and monitor the progress of a cone crop where squirrels are active.

Determining Cone Maturity

Cones and seeds of southwestern ponderosa pine mature several weeks before normal cone opening. Present collection methods are based on picking closed cones during the period between cone (seed) maturity and seed shed. If only a small amount of seed is needed, the best time to collect is when the cones on some trees are beginning to open. By that time, seeds have matured in other trees with closed cones. At best, the time available to collect closed cones using this approach is only a week to 10 days, limiting the amount of seed that can be collected.

To obtain a large amount of seed for regeneration programs, it is necessary to determine the earliest date when an acceptable degree of seed maturity has occured so that mature seed can be collected for a maximum time before the cones open.

The relationship between declining cone specific gravity (cone density, primarily due to moisture content) and increasing seed germination has been applied in other regions as an index to seed maturity (Maki 1940, Schubert 1955, Stoeckeler and Slabaugh 1965, and Van Deusen and Beagle 1973). A study of the cone specific gravity-seed maturity relationship was recently completed for southwestern ponderosa pine.[3] The experimental

[3] *Rietveld, W. J. Cone specific gravity as a seed maturity index for southwestern ponderosa pine. (Manuscript in preparation).*

methods and technical interpretations will be presented in that paper; only the application with be discussed here.

Because climatic factors that affect germination vary from year to year, and local environment affects seed development on individual trees, cones cannot be expected to mature on the same date each year, nor can all trees be expected to mature cones at the same time. One reliable factor, however, is that the specific gravity of the cones will decrease with time, and the enclosed seeds will be closer to maturity. This relationship between declining cone specific gravity and increasing seed maturity will hold true from year to year, since it is independent of the calendar year.

When a certain mean cone specific gravity is reached in a stand, a certain percentage of seed viability can be expected when cones are collected from all trees in that stand. Note that the specific gravity-cone maturity relationship holds true for the cones in a population of trees, not for the population of cones in a single tree. Because cones on different trees may resist moisture loss or dry prematurely due to differences in thickness of cuticle, exposure, or surface area, the relationship in individual trees may not follow exactly the same pattern as the mean of the population. Thus, early collections of cones from "mature" individual trees which pass the test will yield a lower proportion of mature seeds than indicated by their cone specific gravity. It is best, and much easier, to wait until the population mean cone specific gravity goes below 0.88, and then collect cones from the entire stand of trees.

Progress of seed maturity in a sample of 30 trees is shown for the period September 9 to November 6, 1974 (fig. 4). Sampling began on September 9, at that time, 28.7% of the trees yielded mature seeds. By September 30, 73.4% bore mature cones and seed. Most of the trees, 93.3%,matured their cones by October 10. If collections were begun when the minimum acceptable viability of filled seed was 80%, this proportion of the trees would have mature cones on October 4, 1974. This minimum 80% seed viability coincided with a population mean cone specific gravity of 0.88 in 1974 (see footnote 2). On a given date, cone specific gravity did not vary significantly for cones on a single tree, but did vary widely among trees. Therefore, it is important that an adequate number of trees be sampled to obtain an accurate estimate of mean cone specific gravity.

The floatation test, where cones are floated in a test fluid, is recommended for use in the Southwest. The specific gravity of the test fluid must be equivalent to the critical value for cone ripeness. SAE 10W and 20-20W motor oils have a specific gravity of about 0.88 at 60° F.[4] Approximately 2 quarts in a sealable container is enough to conduct the test.

When 13 or more of a sample of 25 cones float in oil, it is safe to begin collections. Because variation in cone specific gravity within a tree is small

[4] *Specific gravity of SAE 10W and 20-20W varies between 0.87 and 0.89 depending on the manufacturer and application. Truck engine oils have slightly higher specific gravity.*

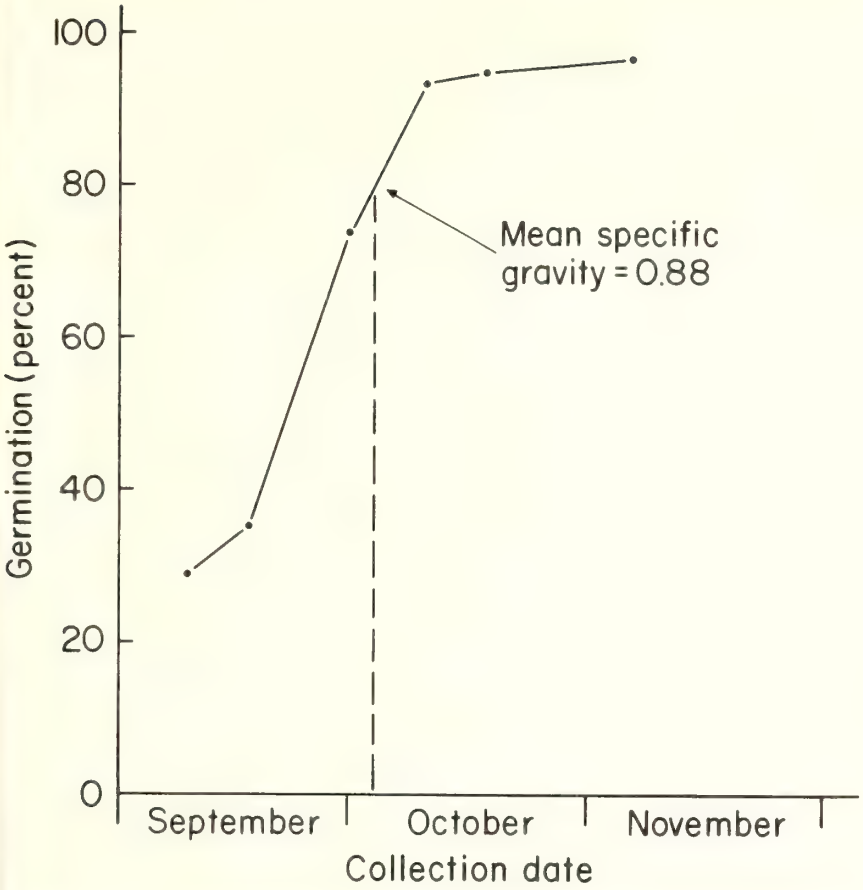


Figure 4.—Seed viability increased rapidly from mid-September to early October. Mean cone specific gravity was 0.88, and 80% of the seed were mature on October 4, (dashed line), the time to begin collecting in 1974. In other seed years, the seed viability line will have the same shape, but will shift to the left or right, depending on growing conditions. The date to begin collecting can vary two weeks or more in different years, and the period to cone opening may vary from 2 to 6 weeks.

and variation among trees is large, one cone should be sampled from each of 25 trees scattered over the area. It is convenient to first collect the 25 cones, seal them in a plastic bag to prevent excessive drying, and test them within 2 hours. Cones should be free of stems, needles, dirt, etc., when tested. When any part of a cone breaks the surface of the test fluid, it is counted as a "floater." Those that sink have a specific gravity greater than 0.88, and may be retrieved with an ice pick.

The area of application of a single cone maturity test is uncertain. Until specific information is available, a cone maturity test should be restricted to no more than one square mile within a continuous timber type and 500 feet of elevation change.

The drying trend of cones is slow at first, and cone specific gravity persists at fairly high levels, averaging around 1.00. At some point (mid-September in 1974) the cones "die" and then dry very rapidly. When this stage is entered, more frequent floatation tests are needed. Rainfall during this period slows the drying trend only briefly; in 1 or 2 days the cone drying trend resumes.

During the moderately wet fall of 1974, the cone collection period extended from October 4 to mid-November. Cones on some trees began opening by November 6, but many trees had closed cones as late as November 15. Under hot, dry, windy fall conditions, the cone collection period may be reduced to as little as 2 to 3 weeks, and collections must begin promptly after average cone specific gravity for the stand reaches the critical value.

Some precaution is necessary when gathering seed on logging operations. It is imperative that the float test be applied only to cones freshly picked from newly-felled trees; cones dry out rapidly on felled trees, and after a few hours their specific gravity is meaningless. Either logging should wait until the cones are judged to be sufficiently mature for collection, or cone collections should wait until mean specific gravity of cones obtained from freshly fallen trees is below the critical value.

There is little difference in the appearance of cones collected too early, say mid-September, and mature cones collected in early October, but low germination and poor storage characteristics of September collections are unacceptable (fig. 4).

It may appear to be a feasible alternative to simply begin cone collection in early October each year, rather than become involved in sampling and floatation tests. However, because of variables such as time of fertilization and climatic conditions during development, the time of 80% seed maturity may vary as much as 3 weeks in successive cone crops. Collections may begin too soon, when much of the seed is immature, or too late, resulting in a shortened collection period. Under prudent management, best efficiency of collection and highest seed quality are attained by collecting during heavier seed years and carefully applying the cone ripeness criterion.

Summary

Cone crop forecasting is needed to help plan regeneration cuttings and seed collections. Heavier seed crops should be favored because seed is of higher quality and easier to collect.

Knowledge of the sequence and timing of development of flowers and crops is basic to cone crop forecasting. The development of a cone crop is described from primordia in buds, to visible flowers, to fertilized ovulate conelets, to mature cones. Female flowers and ovulate cones are the subjects of the field observations.

Early July is the best time to observe the trees (dominants larger than 12 inches d.b.h.) for both female flowers and ovulate conelets. The flower count estimates the potential cone crop for the following year 15 months in advance, and the conelet count estimates the progress of the current year's cone crop 3 months in advance of cone maturity. The 10-unit cone crop rating system should be used for both flower and cone counts; considerable flower and conelet mortality may subsequently reduce the ratings, of course. Forecasts should be made for individual seed zones where seed or seeding is needed.

A cone maturity index is needed to determine the earliest date an acceptable percentage of trees have mature cones and collections may begin. A study of the 1974 cone crop indicated that a population mean cone specific gravity of 0.88 coincided with seed maturity in 80% of the trees the minimum acceptable maturity. The time when cone collections can begin is determined by a floatation test. When 13 or more of a sample of 25 cones float in SAE 10W or 20-20W motor oil, it is safe to begin collection in the area sampled.

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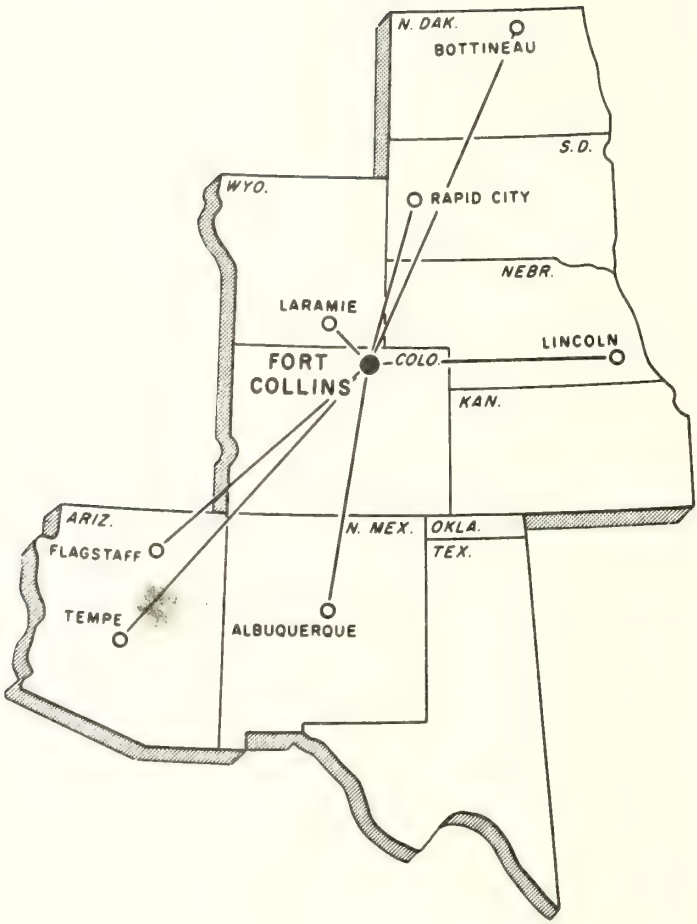
Cone crop forecasting is important for planning regeneration cuttings and seed collections. Knowledge of time and rate of flower and cone development is essential. An early July flower and conelet inspection serves two purposes: (1) a flower count detects 15 months in advance the possibility of a cone crop the following year; (2) a conelet count checks progress of the current year's cone crop. Flower and conelet observations and cone collections should be made on dominant trees larger than 12 inches d.b.h. A population mean cone specific gravity of 0.88 coincides with the time 80% of the seeds are mature. When 13 or more of 25 cones in a sample float in SAE 10W or 20-20W motor oil, it is safe to begin collections in the area sampled.

Keywords: *Pinus ponderosa,* cone crops, phenology.

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